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Supreme Court, U.S.
FILED
JUN 14 1988
JOSEPH F. SPANIOL, JR.
CLERK

No.

IN THE
Supreme Court of the United States
OCTOBER TERM, 1987

UNIROYAL, INC.,
Petitioner,
—v.—
RUDKIN-WILEY CORPORATION,
Respondent.

PREMIX, INC.,
Petitioner,
—v.—
RUDKIN-WILEY CORPORATION,
Respondent.

APPENDICES J THROUGH N TO PETITION FOR WRIT OF CERTIORARI

THOMAS A. BECK
FELFE & LYNCH
805 Third Avenue
New York, New York 10022
(212) 688-9200

WILLIAM R. MURPHY
TYLER COOPER & ALCORN
205 Church Street
New Haven, Connecticut 06509
(203) 789-0700

Attorneys for Petitioners

TABLE OF CONTENTS

PAGE

Appendix J, U.S. Patent 3,241,876 to Saunders A93

Appendix K, U.S. Patent 2,863,695 to Stamm..... A100

Appendix L, Austrian Patent No. 62,329 to Constantin

Original Text..... A105

English Translation A108

Appendix M, Booklet Published by Trailmobile Inc.... A113

Appendix N, District Court Trial Exhibits

Plaintiff Exh. 419 ..... A129

Defendant Exh. KO..... A130

APPENDIX J

PAGE

U.S. Patent 3,241,876 to Saunders A93-A99

March 22, 1966 W. S. SAUNDERS 3,241,876

APPARATUS FOR REDUCING LINEAR AND LATERAL WIND RESISTANCE IN A TRACTOR-TRAILER COMBINATION VEHICLE

Filed Jan. 31, 1964 3 Sheets-Sheet 1

FIG. 1

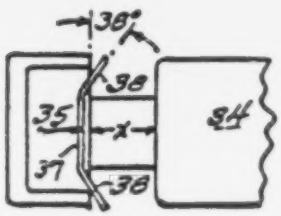


FIG. 2

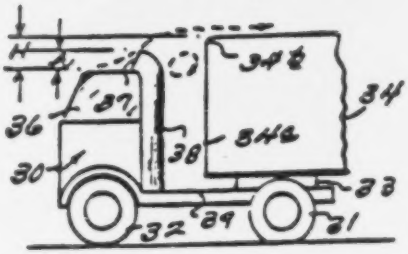


FIG 3

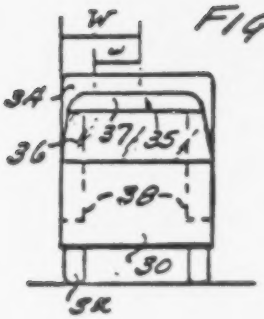


FIG 4

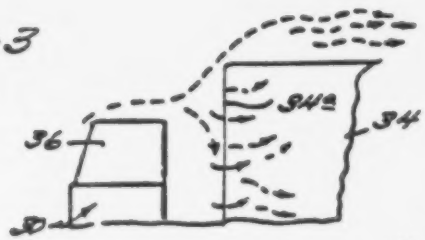


FIG 5

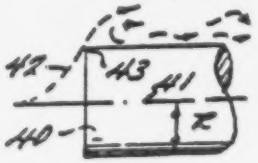


FIG 6

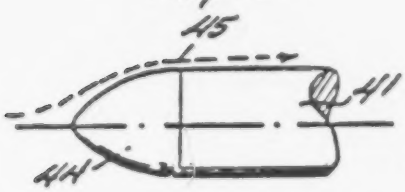


FIG 7

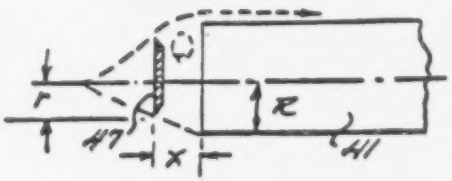


FIG 8

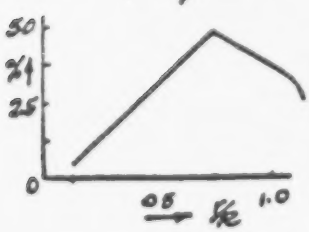
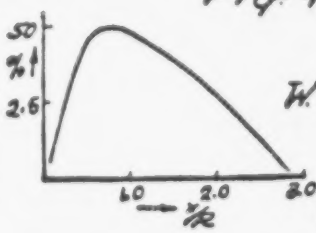


FIG 9



INVENTOR
W. SELDEN SAUNDERS

D. Paul Weiner
ATTORNEY

March 22, 1966 W. S. SAUNDERS 3,241,876

APPARATUS FOR REDUCING LINEAR AND LATERAL WIND RESISTANCE IN A TRACTOR-TRAILER COMBINATION VEHICLE

Filed Jan. 31, 1964 3 Sheets-Sheet 3

FIG. 11

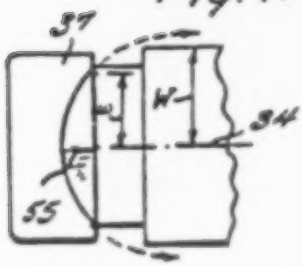


FIG. 10

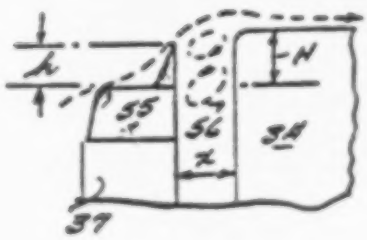


FIG. 12

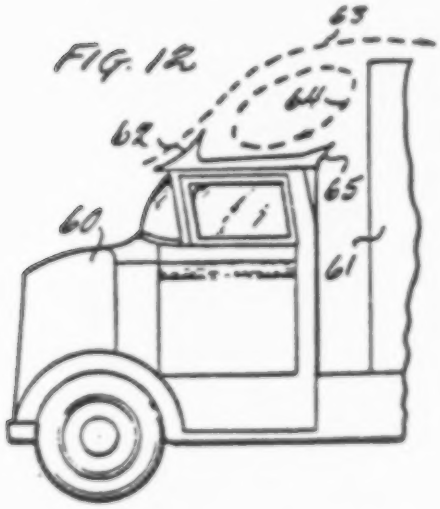


FIG. 13

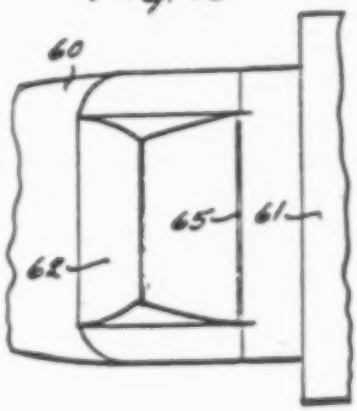


FIG. 14

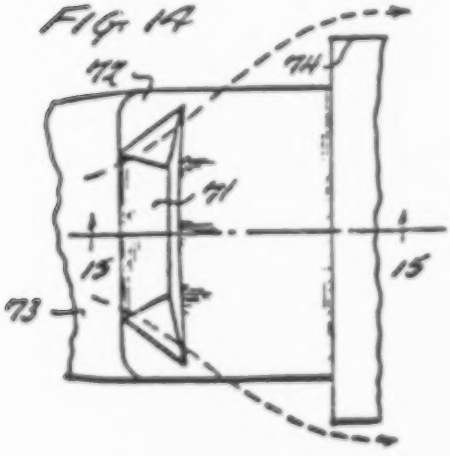
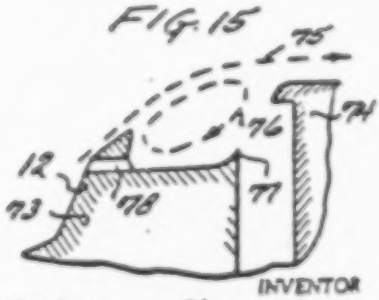


FIG. 15



INVENTOR
W. SELDEN SAUNDERS

BY D. Paul Weaver
ATTORNEY

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March 22, 1966 W. S. SAUNDERS 3,241,876

APPARATUS FOR REDUCING LINEAR AND LATERAL WIND RESISTANCE IN A TRACTOR-TRAILER COMBINATION VEHICLE

Filed Jan. 31, 1964 3 Sheets-Sheet 3

FIG. 16

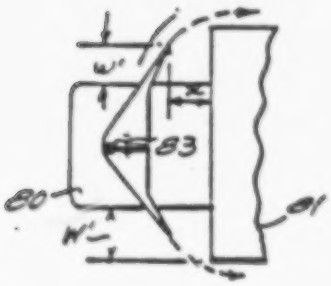


FIG. 17

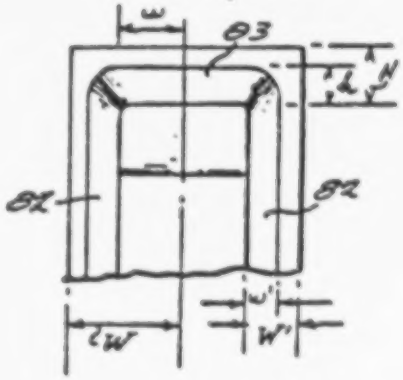


FIG. 18

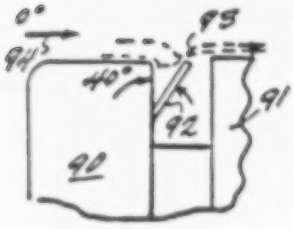


FIG. 19

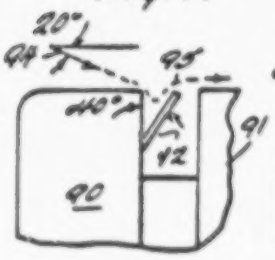


FIG. 20

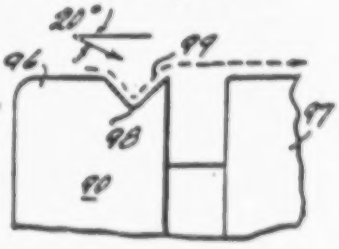


FIG. 21

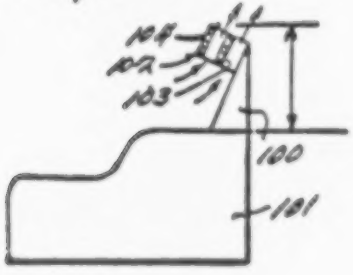


FIG. 22



INVENTOR
W. SELDEN SAUNDERS

BY D. Paul Weaver
ATTORNEY

United States Patent Office 3,241,876
Patented Mar. 22, 1966

3,241,876
APPARATUS FOR REDUCING LINEAR AND LATERAL WIND RESISTANCE IN A TRACTOR-TRAILER COMBINATION VEHICLE

Walter Selden Saunders, 8014 Bradley Blvd., Bethesda, Md.

Filed Jan. 31, 1964, Ser. No. 341,622
4 Claims. (Cl. 296—1)

This invention relates to apparatus for reducing the wind resistance or drag effecting the linear movement of a tractor-trailer combination, as well as reducing the yaw or side sway occasioned by a cross wind, and constitutes a continuation-in-part of my copending application Serial No. 215,424, now abandoned, filed August 7, 1962, entitled, Device to Reduce the Air Resistance of Trucks.

A primary object of this invention is the provision of apparatus adapted to be connected or attached to a tractor or trailer in a combination vehicle which will effectively reduce the wind resistance to forward movement, or drag thereof.

A further object of the invention is the provision of apparatus of this character which will also effectively reduce the side sway or yaw of such a combination vehicle as effected by a transverse or cross wind during the forward travel of the vehicle.

An additional object of the invention is by reducing the resistance of drag and yaw to reduce fuel consumption, diminish driver fatigue, and enhance dynamic stability on the road, as well as to accelerate the speed of transit of the vehicle.

Still another object of the invention is the provision of a device of this character which will operate in a manner different from that of previous devices which contemplate similar results, in that, rather than streamlining the vehicle body, either the tractor or trailer, to afford a smooth and uniform air flow, thus creating a difficult manufacturing problem, as well as reducing the body capacity of the vehicle, the device of the instant invention produces a relatively wide diffusion of the air impacting the forward portion of the trailer, and causes the same to readhere to the body of the truck rearwardly of the front portion thereof in a relatively smooth and even manner, while at the same time creating a low pressure area or bubble between the tractor and the front of the trailer, so that the trailer will, in effect, be pushing forward against reduced rather than increased resistance.

As conducive to a clearer understanding of this invention, it may here be pointed out that applicant is aware that various methods have heretofore been proposed for reducing the drag of vehicles of this nature. Such methods have, however, followed conventional streamlining techniques, a streamlined body being generally considered to be one in which the flow experiences minimum separation from the surface of the body. Since a trailer truck is not a streamlined body, because the flow will normally separate from all of the relatively sharp edges of the truck, such conventional techniques have been uniformly unsatisfactory. The conventional streamlining techniques heretofore applied have attempted to minimize the forward separation of air by either rounding the forward corners of the truck, employing streamlining vanes or guide vanes to keep the air separation to a minimum, or enclosing the tractor-trailer gap with some form of fairing. The instant invention, which is concerned only with the drag arising from the separation occurring at the forward portions of the truck and not with drag due to separation at the rear of the trailer, differs from the above in that there is employed a deflecting device mounted on the tractor which deflects the onrushing air in such manner as to occasion a very large separation of the air flow.

This deflection is made to occur, however, in such fashion that the flow moves convexly across the gap between the tractor and trailer and reattaches to the forward periphery of the trailer. This separation causes a low pressure bubble to be formed in the gap between the tractor and trailer, and although a large separated region exists, the flow pattern which is set up results in a very material drag reduction due to the lowered resistance encountered by the forward portion of the trailer. As expected, such a deflector added to a tractor alone will increase its drag, but the drag of the combination is significantly and unexpectedly reduced. It is a primary object of this invention therefore to provide an attachment which produces a material reduction in the drag of a trailer-tractor combination, and the consequent inherent benefits of such reduction, in accordance with the principles outlined above

Still other objects reside in the combinations of elements, arrangements of parts, and features of construction, all as will be more fully pointed out hereinafter and disclosed in the accompanying drawings.

In the drawings:

FIGURE 1 is a partially schematic and partially broken away top plan view of a tractor-trailer combination provided with a deflector or shield in accordance with a preferred embodiment of the instant invention, parts thereof being broken away.

FIG. 2 is a side elevational view of the portions of the vehicle schematically shown in FIG. 1.

FIG. 3 is a front elevational view of the structure of FIGS. 1 and 2.

FIG. 4 is a diagrammatic fragmentary side elevational view illustrating the turbulent air flow of a conventional tractor-trailer combination vehicle without the deflector of the instant invention.

FIG. 5 is a diagrammatic view illustrating the flow pattern of air over a cylinder whose axis is parallel to the direction of the flow.

FIG. 6 is a similar view of the flow pattern which occurs when the cylinder of FIG. 5 is shielded by a typical streamlined fairing or nose cone.

FIG. 7 is a similar view which discloses the flow pattern when the cylinder of FIG. 5 is shielded by a disk, illustrating the principles of the instant invention.

FIG. 8 is a graph disclosing the percent of drag reduction for the cylinder and disk of FIG. 7 over that of the cylinder of FIG. 5 for various ratios r/R, where r represents the radius of the disk and R the radius of the cylinder.

FIG. 9 is a graphic representation of the percentage of drag reduction for a cylinder and disk in accordance with FIG. 7 over the cylinder of FIG. 5 for various ratios of x/R where x is the distance of the shield from the end of the cylinder and R is the radius of the cylinder.

FIG. 10 is a schematic side elevational view of a modified form of deflector in accordance with the construction of FIG. 1 omitting the side shields.

FIG. 11 is a top plan view of the structure of FIG. 10.

FIG. 12 is a side elevational view of a modified form of deflector shown as applied to the roof of a tractor unit omitting the side deflector plates for the control of yaw.

FIG. 13 is a top plan view of the deflector of FIG. 12.

FIG. 14 is a top plan view of a modified form of construction.

FIG. 15 is a sectional view taken substantially along the line 15—15 of FIG. 14.

FIG. 16 is a top plan view of a further modified form of deflector adapted to be employed when the tractor is narrower than the trailer and including the side deflector shields.

FIG. 17 is a schematic front elevational view of the shield and tractor cab of FIG. 16, parts thereof being broken away.

A 97

FIG. 18 is a top plan view of a portion of a tractor-trailer unit illustrating diagrammatically a completely masked shield and indicating the air flow when the relative wind is dead ahead.

FIG. 19 is a view similar to FIG. 18 but disclosing the change in air flow effected by a masked shield at large angles of yaw.

FIG. 20 is a view similar to FIG. 18 but disclosing a masked side shield constructed integrally with the tractor body.

FIG. 21 is a schematic side view of a conventional tractor cab provided with a shield in accordance with the instant invention, illustrating the employment of a series of turning vanes to augment the action of the deflector of the instant invention.

FIG. 22 is a fragmentary view showing a deflector vane associated with a box on the top of a tractor roof.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Having reference now to the drawings in detail, and more particularly to FIGS. 1, 2 and 3, there is herein shown a preferred embodiment of the inventive concept as applied to a tractor-trailer combination wherein the height of the tractor cab is substantially less than the height of the trailer, but the width is substantially the same, as frequently occurs under present-day conditions. The tractor is generally indicated at 30, and includes in addition to the usual driving and steering wheels 31 and 32, a fifth wheel assembly 33 upon which the forward end of the trailer 34 is mounted in conventional fashion. The instant invention comprises a plate or deflector generally indicated at 35 mounted on the roof of the cab 36 of the tractor, and at a predetermined distance from the normal forward end 34a of the trailer. The shield includes a central portion 37 which is inclined upwardly and rearwardly toward the front of the trailer, and a pair of rearwardly inclined opposite side portions 38, which extend the full height of the body of the tractor above its bed or frame 39. It has been determined by experimentation, as will be more fully described hereinafter, that the height of the shield 35 and its distance from the forward end of the trailer determine to a large extent the effectiveness of the shield in decreasing drag or wind resistance. As shown in FIG. 4, in a tractor-trailer combination dimensioned in accordance with that disclosed in FIGS. 1 to 3, but without the provision of a shield such as disclosed, the air flowing over the forward end of the cab is deflected to a minor extent and impinges directly on the flat front surface of the trailer. This creates a marked increase in wind resistance in the gap between the tractor and trailer and sends air, as indicated by the arrows in FIG. 4, in a highly turbulent condition about the sides and over the top of the vehicle. With a top shield constructed in accordance with the instant invention the air flow follows the course of the arrows in FIG. 2, being deflected upwardly to a distance above the sharp corner 34b at the top of the trailer and then reattaching itself smoothly to the top surface at a position beyond the abrupt juncture. This smooth air flow creates a reduction in pressure in the space between the rear of the tractor and the front of the trailer, and such air as flows into this area circulates, as indicated diagrammatically in FIG. 2, in reduced pressure eddies. In consequence the forward end of the trailer is travelling against a reduced pressure area, and a material reduction in drag is thus effectuated.

The side shields 38 offer little or no resistance to the forward passage of the tractor when travelling directly into the wind, or when the only wind pressure is occasioned by velocity, and serve to prevent the influx of air around the sides of the rear of the tractor into the gap between the tractor and trailer wherein the reduced pressure air circulates in eddies. The primary function of the side plates is, however, to preclude the entrance of air into the gap under those conditions wherein the

direction of travel of the vehicle is angular to the direction of the wind. Under such wind conditions air impinging against the front of the trailer has frequently materially increased the normal yaw or side sway of the trailer to a point of danger. As will be more fully pointed out hereinafter, the provision of the angularly and rearwardly extending baffles reduces to a material extent the yaw and drag produced by a cross wind.

The relation of the height of the shield or baffle to the difference in height between the roof of the tractor and the roof of the trailer as well as the distance of the deflector from the front of the trailer constitute an important feature in deriving optimum results. Extensive wind tunnel tests have resulted in the derivation of an empirical formula for the proper determination of this height and width. Such tests have been conducted primarily with a cylinder, as shown in FIG. 5 at 40, in a wind tunnel. In FIG. 4 with the center line of the cylinder as shown at 41 there is disclosed an example of the drag arising from the separation of the flow from the forward portion, the separation arising as at 42, and separating at the sharp edge 43 of the cylinder face creating a turbulent wake along the sides of the cylinder and resulting in an extremely large drag. This reaction is comparable to and typical of the forward face of a trailer vehicle in motion. If a rounded nose cone 44 is added to the cylinder 41 as shown in FIG. 6 providing a conventional streamlined nose, the separation of the flow is prevented and a relatively smooth air flow as indicated at 45 is provided materially reducing the drag. FIG. 7 discloses schematically the theory of applicant's invention which constitutes the provision of a baffle, or deflector 47, in this case in the form of a disk in front of the cylinder. Disks of different radii r were positioned at different distances x in front of the cylinder and tested in an open jet wind tunnel. The results are disclosed in the graph of FIG. 8 wherein the percentage of drag reduction of the combination of cylinder and disk over the cylinder alone is plotted versus the ratio r/R where R is the radius of the cylinder. FIG. 9 is a similar graph plotted in variations of the distance x between the disk and the cylinder face in relation to R, the radius of the cylinder. By means of these tests it was discovered that a maximum drag reduction of approximately fifty percent is achieved when r/R equals 0.7 and x/R equals 0.7. This drag reduction is very slightly less than that measured with the nose cone of FIG. 6 and represents a substantial drag reduction. The application of the knowledge gained by such tests and the application thereof to devices for the reduction of drag in tractor-trailer combination vehicles in such cases where a conventional nose cone or fairing is not practical constitutes a primary element of the instant inventive concept. Rather than preventing the separation of the streamline by a round nose cone of conventional type, the addition of a large deflecting disk or shield forces a wide separation of the air approaching the cylinder but the position and angle of the streamline are fixed in such a way that the flow curves convexly over the gap between the disk and the cylinder, or, alternatively, between the tractor and the trailer, and reattaches to the periphery of the cylinder or sides of the truck in substantially parallel relation to its sides. The interior of the gap between the two elements is at relatively low average pressure and is filled with quasi-stable eddies or bubbles as indicated in FIG. 7 and again in FIG. 2. Although these eddies exist, there is no violent interaction with the flow around the body and no violent wake is produced, and although a large region of separated flow exists, the drag remains relatively low.

The application of these principles to a deflecting device attached to a tractor as in FIG. 1 is further illustrated in FIGS. 10 and 11. Here a deflector 55 in general similar to the portion 37 of the deflector 35 is mounted on the top of a tractor which is spaced a distance x from a trailer 34. The difference in height between the roof of

the tractor and that of the trailer is indicated by H, while the height of the shield constructed in accordance with the previously derived shield is indicated by *h*. The arcuate deflector 55 which is inclined rearwardly forces the air out of its usual path before it reaches the gap region. The flow then curves convexly back across the gap and reattaches to the periphery of the trailer in a direction which is substantially parallel to the sides and top of the trailer. The gap is filled with quasi-stable eddies 56 as previously indicated in connection with FIG. 2, which eddies are isolated from the main flow and at relatively low pressure. The situation is substantially identical to that described in connection with FIG. 7. The baffle or deflector 55 and the air deflected thereby form a shield which precludes the relative wind from striking the front of the trailer and entering the gap between the tractor and trailer. Similarly, a region of low pressure is created in the gap and the trailer thus follows the tractor in a partial vacuum materially reducing the overall drag and rendering the unit more stable. In computing the height of the shield as used on the roof of the truck as shown in FIGS. 10 and 11 with the shield having a half width *w* and a height *h* and spaced as previously stated a distance *x* from the trailer it has been found that by employing the empirical formula previously discussed, that W corresponds to R and that the curves of FIGS. 8 and 9 depict the approximate variation of the drag reduction within the parameter previously defined. Thus a maximum drag reduction is obtained when x/W equals 0.7 and w/W equals 0.7. Applying the formula r/R to the height of the shield and substituting therefor h/H a curve similar to FIG. 8 is produced so that when *h* equals 0.7H a maximum drag reduction is achieved.

As shown in FIG. 8, effective, though not optimum results may be obtained when the height ratio of the shield or h/H is between 0.5 and 0.9. Similarly, as shown in FIG. 9, a wide variance in the ratio of the distance of the shield or baffle from the front of the trailer, or w/W is effective, though in progressively decreasing increments, over a range between 0.3 and about 2.0.

The frontal shape of the shield may vary, and it has been found advantageous to round the corners of the shield with a radius of about $\frac{1}{5}h$, although the rounded corners are not essential to the achievement of material drag reduction with the shield in the instant invention. FIGS. 12 and 13 disclose a modified form of shield embodying the basic inventive concept but which is more adapted to use where the relative gap between the tractor 60 and the trailer body 61 is relaitvely small. Here a shield or baffle 62 is provided on the forward edge of the roof of the trailer cab to deflect the main stream of air upwardly as at 63 and over the roof of the trailer while turning back a portion thereof to form an eddy or bubble 64 which serves further to deflect air from the front of the trailer 61, reducing the drag of the combination. A lip 65 may be provided at the rear of the cab roof which serves to assist in retaining the eddy 6 and in preventing further interchange between the outside air and the air in the gap between the rear of the tractor and the trailer.

FIGS. 14 and 15 disclose a further modification of the structure of FIGS. 12 and 13 wherein a shield 71 is provided adjacent the forward edge of the cab 72 of a tractor 73, which is provided with a trailer 74. Here the air flow 75 is similar to that shown at 63 in FIG. 12 and an eddy 76 is provided. A lip 77 corresponds to the lip 65. However, in this modification the shield is provided with a slot 78, which allows a second current of air to flow along the roof and over the lip 77, which further stabilizes the bubble 76 and precludes the entrance of air into the gap between the tractor and trailer.

If a cross wind is blowing over the road the vehicle is traversing, a relative wind at an angle of yaw as great as or sometimes greater than twenty degrees may be encountered. At a large angle of yaw the shield or deflector loses a certain amount of its ability to deflect the air around the windward side of the trailer and a material quantity of wind enters the gap between the tractor and trailer to increase the drag. This may be countered to some extent by extending the top shield to its legal limit, that is where w/W equal 1, but this reduces the performance when the wind is dead ahead. A consideration of FIG. 8 discloses that the peak showing the percent of drag reduction x/R and therefore x/W is not as sharply peaked as that for h/H. The center of the shield may be therefore moved forwardly on the tractor roof without seriously affecting its ability to reduce the drag at a zero angle of yaw. This change in shape, however, increases the deflection on the windward side up to a large angle of yaw and therefore an increase in w/W is not necessary. The curvature of shield 55 accomplishes this to some extent. Although the shield now resembles a wrap-around windshield for a conventional vehicle, and has a pleasing appearance, its opertaion is exactly the opposite of that of a wrap-around windshield in that the curved and slanted windshield keeps the separation to a minimum while the deflecting shield 55 is shaped so as to provide a separation of the flow in accordance with the precepts of the instant invention.

The flow of air around the sides of the truck behaves in a manner similar to that over the top, obviously, and in cases where the tractor vehicle 80, as shown in FIGS. 16 and 17, is materially narrower than that of the trailer 81, a shield 82 is provided along each edge of the cab extending downwardly from a central forwardly peaked top shield 83. It has been determined that the distance w'/W' equals 0.7 where w' equals the extension of the shield beyond the edge of the tractor and W' equals the width of extension of the trailer beyond the side of the tractor most advantageous results are provided. The side edges 82 preferably extend beyond the ends of the top shield 83 and should be merged in a smooth curve as shown in FIG. 17. Such side shields can be extended rearwardly as shown in FIG. 16 and should be located as close as possible to the trailer while still allowing a ninety degree maximum rotation of the tractor and a four inch minimum clearance space between the tractor and trailer at any angle of rotation. Preferably the side shields are slanted back to a material extent.

A material improvement in performance is effected by the structure of FIG. 1 when, if the tractor is sufficiently wide, its body may be used to mask a portion of the side shield when the wind is dead ahead. In this case a side shield may be used which is large enough to give a very material drag reduction at large angles of yaw, but which will be completely masked so that the zero yaw performance when the wind is head ahead is completely unaffected. The preferred embodiment of the invention as shown in FIG. 1 incorporates such a principles which is further schematically illustrated in FIGS. 18 and 19. Here the tractor vehicle 90 is provided in the gap between it and its associated trailer 91 with a vertically positioned deflector plate 92. The preferred angle of declination to the rear has been found by experiment to be approximately forty degrees, as illustrated also in FIG. 1. When the wind is dead ahead or the yaw angle is zero as illustrated at 94, the air flow is indicated at 93, the shield having thus virtually no effect on the drag of the vehicle. However, when a cross wind is blowing and the angle of yaw is twenty degrees or less as shown at 94 in FIG. 19, the air flow path is indicated at 95, where the air flowing sharply around the rear corner of the tractor is deflected by the shield 92 in a manner similar to that previously described, and passes smoothly along the sides of the trailer, being completely excluded from the gap therebetween.

A modification of this principle is shown in FIG. 20 which discloses schematically the top of a tractor 96 and its associated trailer 97 having a gap therebetween wherein the side of the tractor is formed with a vertical recess 98, which deflects the air path at 99 away from the gap between the tractor and trailer in substantially the same manner as the shield 92 previously described.

Such side shields and/or masked side shields may be also advantageously employed between two trailers which are connected in a train, or in any surface in which there exists a gap. Preferably the masked side shields merge smoothly with the roof shield as shown in the embodiment of FIGS. 1, 2 and 3.

Under certain circumstances where, for example, it is necessary to keep the deflector height as low as possible, a deflector with an actual height h less than 0.7H may be built to accomplish a very material flow reduction. Such a modified form of the invention is disclosed in FIG. 21 wherein a deflector 100 is mounted on the roof of a tractor 101 followed by the usual trailer, and wherein the height of the deflector h' is equal to substantially 0.5H where H is the height of the trailer. In this case a box-like structure 102 is provided at the top forward face of the shield 100 containing parallel deflector plates 103 and its face plate 104. By this means a total deflection large enough to produce a flow that will attach to the following body and form a bubble or eddy of the proper dimension may be employed.

In some instances where the roof of the cab of the vehicle is occupied by a box-like structure such as an air conditioner or the like for example, this structure will not in itself provide any separation of flow sufficient to provide material drag reduction. However, under these conditions the provision of a vane 105 forwardly of and extending slightly above the rounded corner of the box 106 as shown in FIG. 22 will cause a widely deflected air stream 107, as illustrated by the arrows, and produce a sufficient deflection to cause the air stream to readhere to the sides of the trailer creating a bubble or eddy in the space between the trailer and the tractor as previously described.

Obviously many other expedients may be employed to achieve the principle of the instant invention, although there are herein disclosed certain preferred embodiments thereof.

From the foregoing it will now be seen that there is herein provided an improved shield or deflector for attachment to the tractor of a tractor-trailer combination, or which may be integrally manufactured therewith, which produces a material reduction in the drag of the combination, and consequent saving in time, expense and driver effort, whereby the effective capacity of the vehicle is no way reduced and which minimizes the effects of yaw or cross wind on the vehicle, which accomplishes all of the objects of this invention, and others, including many advantages of great practical utility and commercial importance.

As many embodiments may be made of this inventive concept, and as many modifications may be made in the embodiment hereinbefore shown and described, it is to be understood that all matter herein is to be interpreted merely as as illustrative, and not in a limiting sense.

I claim:

1. In combination with a tractor-trailer vehicle having a gap between the tractor and the trailer, said tractor being of less height than said trailer, an airflow deflecting baffle mounted to extend above the cab roof of said tractor for diverting the air flow relatively widely in a manner to avoid entry of the air stream into said gap thereby creating at least one low pressure air eddy in said gap to reduce the frontal air pressure against the trailer, said diverted air reattaching to the trailer at points spaced rearwardly of said gap, said baffle being inclined vertically rearwardly and forwardly convexed in a horizontal plane, positioned a distance from the front of the trailer equal to approximately 0.7 the half width of the trailer end of a height substantially 0.7 of the difference in height between the tractor cab roof and the roof of the trailer.

2. In combination with a tractor-trailer vehicle having a gap between the tractor and the trailer, an air flow deflecting shield comprising a baffle mounted to extend above the tractor cab roof, said baffle being vertically inclined rearwardly and forwardly convexed in a horizontal plane, said baffle having a predetermined height substantially 0.7 of the difference in height between said cab roof and the trailer roof, said baffle being positioned a distance from the front of the trailer equal to approximately 0.7 the half width of the trailer.

3. In combination with a tractor-trailer vehicle having a gap between the tractor and the trailer, said tractor having a cab with the roof thereof of less height than said trailer, a substantially solid upstanding air flow deflecting baffle mounted to extend above the cab roof and having its lower edge in substantially air impervious relation therewith, for diverting the substantially entire air flow relatively widely in a manner to avoid entry of the air stream into the gap, thereby creating at least one low pressure air eddy in said gap to reduce the frontal air pressure against the trailer, the diverted air reattaching to the trailer at points spaced rearwardly of said gap, said baffle being of a height between 0.5 and 0.9 of the difference in height between the tractor cab roof and the roof of the trailer, and being positioned a distance from the front of the trailer equal to between 0.3 and 2.0 times the half width of the trailer.

4. The structure of claim 3 wherein said baffle is positioned immediately adjacent the rear of the cab roof.

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A. HARRY LEVY, *Primary Examiner.*
MILTON BUCHLER, *Examiner.*

APPENDIX K

PAGE

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A 100

Dec. 9, 1958 A. F. STAMM 2,863,695

TRACTOR-TRAILER AIRSTREAM CONTROL KIT

Filed Nov. 19, 1954 2 Sheets-Sheet 1

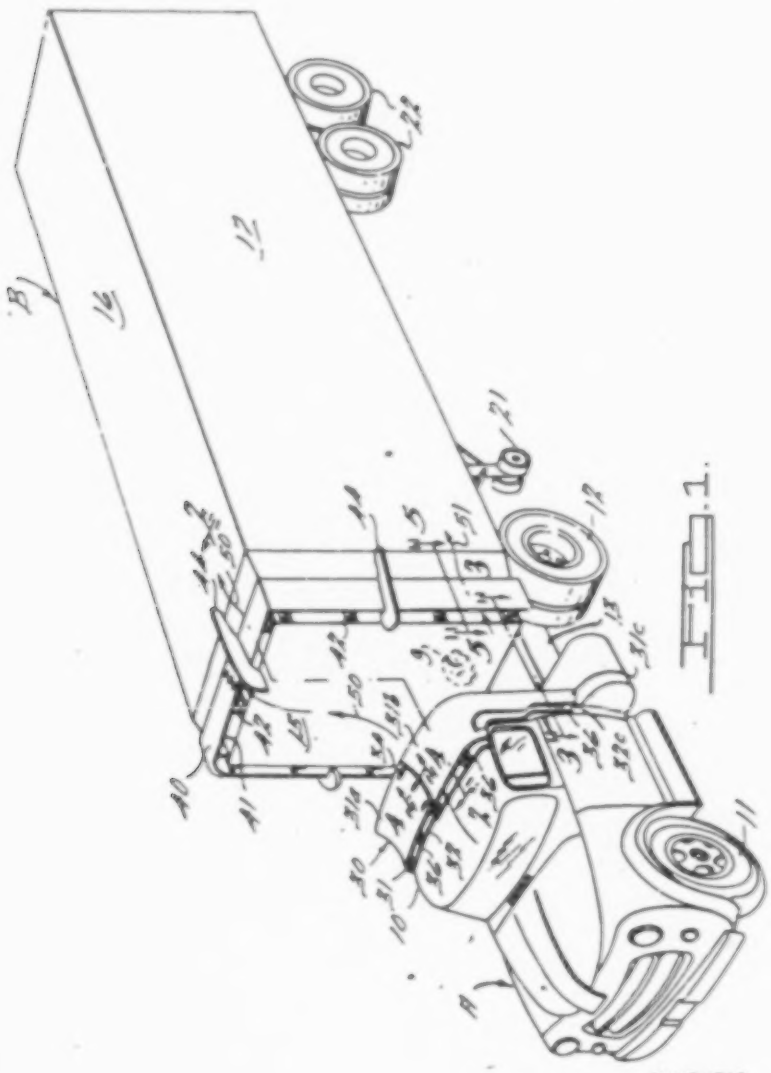


FIG. 1.

INVENTOR.
Alexander F. Stamm
BY
Harness and Harris
ATTORNEYS

Dec. 9, 1958 A. F. STAMM 2,863,695

TRACTOR-TRAILER AIRSTREAM CONTROL KIT

Filed Nov. 19, 1954 2 Sheets-Sheet 2

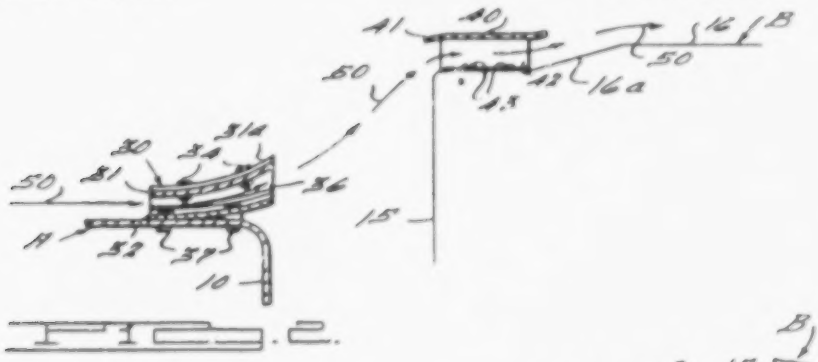


FIG. 2.

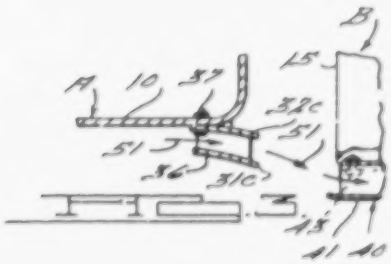


FIG. 3.

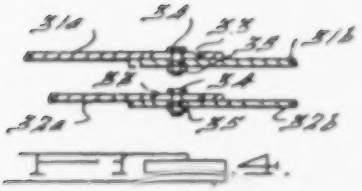


FIG. 4.

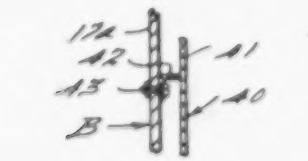


FIG. 6.

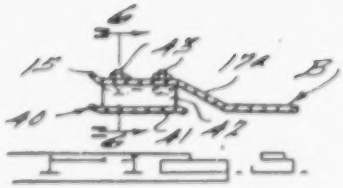


FIG. 5.

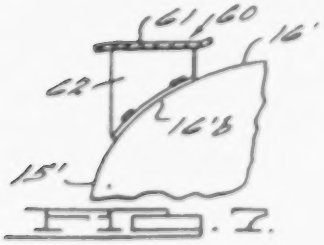


FIG. 7.

INVENTOR.
Alexander F. Stamm
BY
Harness and Harness
ATTORNEYS.

United States Patent Office 2,863,695 Patented Dec. 9, 1958

2,863,695

TRACTOR-TRAILER AIRSTREAM CONTROL KIT

Alexander F. Stamm, Rochester, Mich., assignor to Chrysler Corporation, Highland Park, Mich., a corporation of Delaware

Application November 19, 1954, Serial No. 469,913

2 Claims. (Cl. 296—1)

As a result of a series of comprehensive wind tunnel tests recently conducted on scale models of present day tractor-trailer combinations, and various modifications thereof, a number of revealing conclusions as to tractor-trailer air flow drag losses and their relation to tractor-trailer design have become obvious.

The more important conclusions resulting from the aforementioned tests are:

(1) A significant reduction in horsepower drag losses in tractor-trailer combinations can be achieved by controlling the air flow between the rear of the tractor cab and the front end of the attached trailer body.

(2) Rounding or beveling the top and side edges of the front end of the trailer body produces a significant reduction in tractor-trailer drag losses.

(3) Tractor-trailer drag losses seem to increase with increase in the space between the tractor cab and the front end of the trailer body, at least up to a certain limit.

(4) The use of skirting beneath the tractor front end and along the lower portions of the trailer body sides also reduces tractor trailer drag losses.

(5) Rounding or beveling of the side and top edges of the rear wall of the trailer body has little effect on reducing tractor-trailer drag losses.

(6) The use of streamlining at the rear end of the trailer body, such as by use of a tapering tail section on the trailer body, does not reduce drag losses sufficiently to justify the accompanying reduction in trailer load carrying capacity.

(7) The use of deflecting vanes at the rear end of the trailer body does not produce any significant reduction in tractor-trailer drag losses.

(8) Removal of the tractor under-body-mounted spare tire and its carrier gear, the tractor gas tanks, and projecting frame cross members on the undercarriage of the trailer, does not produce any significant reductions in tractor-trailer drag losses.

The aforementioned wind tunnel tests very definitely established that when streamlining was applied to the region between the rear of the tractor cab and the front end of the trailer body, so as to control the air flow rearwardly from the cab and prevent turbulence in this region, that then a significant reduction in drag losses should result. While it would be most efficient to have a smooth surfaced sheeting extend rearwardly from the periphery of the tractor cab to the peripheral edges of the front wall of the trailer body, so as to completely enclose the space between the tractor cab and the attached trailer body, still, such an arrangement would not be feasible due to the fact that the tractor cab and the trailer body must be free to rotate relative to each other through approximately 180 degrees. Accordingly, it is a primary object of this invention to provide a practical device that may be readily applied to any conventional tractor-trailer combination to control the air flow between the tractor cab and the front end of the trailer so as to significantly reduce the drag losses that normally result from the air flow turbulence in this region.

It is another object of this invention to provide an accessory kit that may be readily applied to the rear portion of a conventional tractor cab and to the front end of the tractor attached trailer body so as to control air flow between the tractor cab and attached trailer body.

It is still another object of this invention to provide an air flow control attachment for the rear portions of tractor cabs that is adapted to guide the air flow rearwardly towards and across the rearwardly located tractor attached trailer body and thereby reduce the drag losses of such a combination of attached vehicles.

It is still another object of this invention to provide an air flow control attachment for the edge portions of the front wall of a tractor drawn trailer body that is adapted to reduce the turbulence that normally exists at the front end of the trailer that is drawn by a conventional tractor.

Other objects and advantages of this invention will become readily apparent from a reading of the following description and a consideration of the related drawings wherein:

Fig. 1 is a perspective view of a tractor drawn trailer equipped with the air flow control device embodying this invention;

Fig. 2 is an enlarged, fragmentary, sectional elevational view taken along the line 2—2 of Fig. 1;

Fig. 3 is an enlarged, fragmentary, sectional elevational view taken along the line 3—3 of Fig. 1;

Fig. 4 is an enlarged, fragmentary, sectional elevational view taken along the line 4—4 of Fig. 1;

Fig. 5 is an enlarged, fragmentary, sectional elevational view taken along the line 5—5 of Fig. 1;

Fig. 6 is an enlarged, fragmentary, sectional elevational view taken along the line 6—6 of Fig. 5; and

Fig. 7 is a fragmentary sectional elevational view of a modified form of front end construction for the trailer body.

In the drawings A represents the motor driven towing tractor vehicle and B represents the towed trailer vehicle that is attached to the tractor A by conventional king pin bearing means 9 that are shown schematically. The tractor A has cab 10 that is of conventional size, location and shape. The tractor cab 10 is usually only about one-half as high as the top of the body of the trailer B and is spaced forwardly of the front wall of the rearwardly positioned trailer B. Wheels 11 and 12 support the chassis frame 13 of the tractor A.

The body of trailer B is essentially an elongated box that includes a front wall 15, a top wall 16, and opposed side walls 17. Trailer B includes conventional landing gear 21 and rear wheels 22.

As has been previously pointed out, considerable drag loss can be eliminated by reducing the air flow turbulence that normally occurs between the rear of the tractor cab 10 and the front end of the towed trailer B. This invention discloses a simplified, readily applied, accessory kit that can be installed on the tractor cab and on the adjacent front end portion of the tractor towed trailer body to materially reduce the drag losses of such a combination of vehicles. It is the prime purpose of this accessory kit to provide a means for readily controlling the air flow from the cab rearwardly across the space between the back end of the tractor cab 10 and the front end 15 of the rearwardly located trailer B. By controlling the air flow across the space between the tractor cab and the trailer body it is possible to direct the manner of air flow across the surfaces of the trailer and thereby keep turbulence to a minimum.

The air flow accessory kit embodying this invention comprises a cab mounted portion 30 and a trailer mounted portion 40. The cab mounted portion 30, see Figs. 1 and 2 particularly, includes a pair of spaced apart shells

31 and 32 that are of a substantially inverted U-shaped cross sectional configuration. The bight portions of the U-shaped shells 31, 32 are adapted to extend across and be suported on the roof of the tractor cab 10 whereas the leg portions of the U-shaped shells 31 and 32 are adapted to extend downwardly along and to be connected to the side walls of the tractor cab 10 adjacent the rear end of the cab 10. Each of the U-shaped shells or shrouds 31 and 32 may be made in two sections which sections are each of substantially L-shaped cross-sectional configuration. The base leg portions 31*a*, 32*a* and 31*b*, 32*b* (see Fig. 4), that overlie the roof of the tractor cab 10 are arranged in overlapping relationship and each of the legs 31*a* and 32*a* has one or more slots 33 that are adapted to receive the bolts 34. Bolts 34 threadably receive the nuts 35 so that the shells or shrouds 31 and 32 may be adjusted in width to fit tractor cabs of different sizes. The shell or shroud elements 31 and 32 have their leg portions 31*c* and 32*c* respectively mounted on and extending downwardly adjacent to the sides of the cab 10 at the rear end portion thereof (see Figs. 1 and 3). Stiffener plates 36 extend between the spaced apart shells or shrouds 31 and 32 to maintain these elements in spaced apart relationship. Bolt type connectors, such as the elements 37, may be used to fixedly mount the shell elements 31 and 32 on the tractor cab 10. Obviously any equivalent screw, clamp or tack welding means could be substituted for the bolt connectors 37 herein disclosed.

It will be noted from Figs. 2 and 3 that the spaced apart shells 31 and 32 are shaped so as to diverge towards the rear of the cab 10. Also, the portions of the shells 31, 32, that overlie the top of the tractor cab 10, are tilted upwardly in addition to diverging so that the airstream flowing rearwardly through the conduit means formed by the spaced shell portions 31*a*, 31*b* and 32*a*, 32*b* will be discharged upwardly towards the upper edge of the front wall 15 of the trailer body. The arrows 50, see Fig. 2, show the airstream control effect that results from passing the airstream discharged from the rear of the tractor cab roof through the spaced shell conduit means 31, 32. It will be noted that the airstream discharged from the shells 31, 32 is directed, as shown by arrows 50, upwardly and rearwardly so that it will pass into the conduit 40 that is located around the periphery of the front wall 15 of the body of the trailer B. This controlled air flow from the rear portion of the tractor cab 10 prevents or substantially eliminates, the air flow turbulence that otherwise results at the front end of the trailer body and as a result drag losses are materially reduced.

The same type of controlled airstream flow occurs along the sides of the tractor cab 10 as occurs across the top of the tractor cab. From Fig. 3 it will be noted that the leg portions 31*c*, 32*c* of the spaced apart shell elements 31, 32 provide a conduit means for collecting and controlling the discharge of the airstream from along the sides of the tractor cab 10. The leg 32*c* of shell 32 is fixed to the cab body 10 by the bolt connectors 37 and spacer plates 36 space the shell legs 31*c*, 32*c*. The shell legs 31*c*, 32*c* diverge rearwardly and are also tilted outwardly from the body of the tractor cab 10 to cause the airstream flow, as indicated by the arrows 51, to pass outwardly from the tractor cab 10 towards the conduit 40 that extends around the front wall 15 of the trailer body. This controlled airstream flow along the sides of the truck cab and the trailer prevents turbulence at the front end of the trailer and reduces drag losses.

The conduit 40 that is fixed to the front end of the trailer body comprises a shell or shroud 41 element of substantially inverted U-shaped cross sectional configuration. This shell element 41 may be composed of two substantially L-shaped sections that are bolted together by bolt and slot connector means similar to the aforedescribed means 33—35. The making of the shroud 41 in adjustably connected sections permits it to be fitted to varying size trailers. The conduit 40 is designed to fit about the edges of the front end of the trailer body in spaced relation thereto so as to provide an airstream conduit to control the discharge of the airstream along the outer surfaces of the trailer body. Shell 41 is held in outwardly spaced relation to the front end of the trailer body by the spacer plates 42. The spacer plates 42 may be fixedly connected to the trailer body and nut connectors 43 or by any equivalent type of connection.

From Figs. 2 and 5 it will be noted that the front end of the trailer is preferably formed with a recessed step-like formation 16*a*, 17*a* that is intended to receive the conduit shell 40. By providing a recess to receive the conduit member 40, the trailer roof can be extended upwardly to the prescribed overhead limits and thus valuable trailer load carrying capacity is not sacrificed. Obviously the conduit member 40 could be mounted on top of a perfectly flat trailer roof if the overhead projection of the conduit member 40 did not present economic or regulatory problems. As indicated by the arrows 50 and 51 in Figs. 2 and 3, the cab conduit or shell member 30 will cause airstream flow along the top and sides of the cab to be directed rearwardly in such a fashion that it will be directed into the trailer mounted conduit shell member 40 and thereafter discharged along the top and sides of the trailer body in a fashion that tends to reduce airstream turbulence and thereby reduce drag losses. The trailer mounted conduit member 40 may also include a number of guide vanes 44 that project into the airstream and assist in controlling its path of flow.

Fig. 7 shows a modified form of trailer mounted, shell-type, airstream gathering and discharge conduit 60. The conduit 60 is adapted to be mounted on the front end of a trailer body 16' that has the edges of its front wall rounded or curved rather than formed with recessed step formations such as 16*a*, 17*a* of the form of the invention shown in Figs. 1–6. The shell member 61 of the Fig. 7 form of the invention is substantially identical to the member 41 shown in Figs. 1–6. However, the spacer support plates 62 for the shell plate 61 in the Fig. 7 form are formed to fit the curvature of the trailer body at its front end. These spacer plates 62 could be made as shown or as adjustable devices to fit different types of body curvatures. In all other respects the shell type conduit 60 of Fig. 7 is similar in structure and function to the shell conduit 40 of the Fig. 1–6 form of this invention.

While this invention shows the airstream control kit for the tractor-trailer combination made in the form of an accessory item that can be added to existing tractors and/or trailers, still, it is within the scope of this invention to form the tractor and/or trailer airflow conduit elements as integral parts of the tractor cab and trailer body if so desired. It is also possible, and within the scope of this invention, to use merely one or the other of the two airflow control conduits under certain circumstances. Also it is a part of this invention to include in combination with the trailer mounted airflow conduit elements, the step-like (Fig. 1) or rounded (Fig. 7) peripheral edge portions of the front wall of the trailer body for these trailer body formations materially assist in controlling the flow through the trailer mounted conduit and thereby reducing turbulence and attendant drag losses.

I claim:

1. In a tractor-trailer combination vehicle having the tractor cab spaced forwardly of the trailer body, a first open-ended, conduit type, airflow control means mounted on the rearwardly located top and side peripheral surface portions of the tractor cab to receive and guidingly discharge the airstream passing rearwardly over the tractor body during forward motion thereof, said first airflow control means being arranged to discharge the

said airstream towards top and side peripheral portions of the front end of the rearwardly positioned trailer, said top and side peripheral portions of the trailer front end being depressed to provide airflow guiding formations, and a second open-ended, conduit, type, airflow control means mounted on the depressed peripheral surface portions of the front end of the trailer to receive the airstream discharged by the tractor mounted airflow control means and to guidingly discharge said airstream rearwardly along the peripheral surface portions of the trailer, said airflow means each comprising an inverted U-shaped frame member composed of a plurality of adjustably interconnected frame elements.

2. In a tractor-trailer combination vehicle having the tractor cab spaced forwardly of the trailer body, a first open-ended, conduit type, airflow control means mounted on the rearwardly located top and side peripheral surface portions of the tractor cab to receive and guidingly discharge the airstream passing rearwardly over the tractor body during forward motion thereof, said first airflow control means being arranged to discharge the said airstream towards the top and side peripheral portions of the front end of the rearwardly positioned trailer,

the top and side peripheral portions of the front end of said trailer having a depressed step formation therein, and a second open-ended, conduit type, airflow control means mounted in the depressed step formation formed around the peripheral surface portions of the front end of the trailer to receive the airstream discharged by the tractor mounted airflow control means and to guidingly discharge said airstream rearwardly along the peripheral surface portions of the trailer.

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APPENDIX L

PAGE

Austrian Patent 62,329 to Constantin

Original Text A105-A107

Translation A108-A112

Klasse 63 c. A 105 Ausgegeben am 25. November 1918.

KAIS. KÖNIGL. PATENTAMT.

Österreichische

PATENTSCHRIFT Nr. 62329.

LOUIS CONSTANTIN IN PARIS.

Einrichtung an Fahrzeugen zur Verminderung des Bewegungswiderstandes.

Angemeldet am 18. März 1913; Priorität vom 18. März 1911 (Anmeldung in Spanien).

Beginn der Patentdauer: 1. Juli 1913.

Es ist bekannt, den Widerstand des Mediums bei Bewegung von Fahrzeugen im Wasser oder in der Luft dadurch herabzusetzen, daß man dem Vorderteil des Fahrzeuges eine zugespitzte Form gibt.

Diese Anordnung, wie sie sowohl bei Schiffen als auch bei Landfahrzeugen und Luftschiffen verwendet wird, sieht zwischen dem vorderen Grate oder dem äußersten Teile des Fahrzeuges, der in das Medium eindringt, und dem Körper des Fahrzeuges eine durch schräge Wände oder gerichtete Flächen gebildete Verbindung vor, welche mit dem Fahrzeugkörper aus einem Stück besteht. Der auf diese Weise entstehende Bug ist notwendigerweise wenig oder schlecht verwertbar und belastet das Fahrzeug mit einer Vermehrung des toten Gewichtes, die keineswegs durch eine Erhöhung des relativen Fassungsvermögens ausgeglichen wird.

Übrigens kann eine Verbesserung eines vorhandenen Fahrzeuges unter diesen Umständen nicht anders erfolgen, als durch die vollständige Umgestaltung des Vorderteiles, die nicht immer möglich ist: Als Beispiel sei ein Automobil mit geschlossener Karosserie, etwa eine Limousine, angeführt, bei welcher man nicht darum denken kann, den Ausblick vollständig zu verdecken, indem man an die Karosserie einen zugespitzten Bug anfügt, der mit ihr einen gemeinsamen Körper bildet.

Die vorliegende Erfindung hat nun in erster Linie den Zweck, die Konstruktion von Fahrzeugen zu ermöglichen, die sehr kompendiös sind, d. h. ein großes relatives Fassungsvermögen zeigen und dank eines besonders gestalteten Ansatzes von geringem Gewicht und kleinem Volumen gleichzeitig dadurch ausgezeichnet sind, daß der Bewegungswiderstand des betreffenden Mediums ein unbedeutender wird. In zweiter Linie bezweckt die Erfindung die Verbesserung vorhandener Fahrzeuge in dem gleichen Sinne, und zwar ohne wesentliche Vermehrung des Gewichtes und ohne zu eingreifende Umgestaltung des Fahrzeuges.

Die Erfindung stützt sich auf die Tatsache, daß die dünnen Schichten des Mediums, die durch einen in Bewegung befindlichen Körper seitlich verschoben werden, auf eine bestimmte Strecke hin fortgesetzt abgelenkt bleiben, auch nachdem sie außer Berührung mit dem genannten Körper gekommen sind, und daß sie in dieser Ablenkung die Schichten des Mediums, denen sie begegnen, mit sich reißen.

Wenn man also in einer entsprechenden Entfernung vor dem Fahrzeug einen Schirm von passend gestaltetem Querschnitt anbringt, der kleiner ist als der des Wagenvorderteiles, so werden die Schichten des Mediums, die durch diesen Schirm abgelenkt werden, auch andere Schichten aus der Bahn des Wagens herausschaffen, welche ohne den Schirm das Fahrzeug getroffen und der Bewegung einen Widerstand entgegengesetzt hätten. Es zeigt sich also, daß das Fahrzeug in diesem Falle nicht den Widerstand einer Säule des Mediums zu überwinden haben wird, die denselben Durchmesser besitzt wie sein Vorderteil, sondern nur jenen einer Säule von dem Durchmesser des Schirmes. Demnach wird eine Verminderung des Widerstandes eintreten. Des weiteren ergibt sich, daß diese Verminderung um so erheblicher sein wird, um so kleiner der Widerstand beim Vorwärtsgange des Schirmes selbst ist, selbstverständlich insoweit das Vermögen der seitlichen Ablenkung dieses letzteren dadurch nicht vermindert erscheint.

Dieses Ergebnis wird der Erfindung gemäß erzielt, indem man die Wände des Schirmes aus Flächen bestehen läßt, die sich in einem Winkel schneiden, wobei die durch die Schnittlinie (den Grat) gelegte Symmetrieebene je nach Erfordernis horizontal oder vertikal stehen kann, die Flächen des Schirmes können ferner auch den Mantel eines Kegels bilden.

Eine sehr starke seitliche Ablenkungskraft läßt sich dadurch erzielen, daß man den Schirm nicht in Form einer einzigen kontinuierlichen Fläche ausbildet, sondern aus einer Anzahl von übereinander gelegten Lamellen herstellt, wobei diese Blätter zweckmäßig gekrümmten Querschnitt besitzen, um Stoß- und zu plötzliche Ablenkungen, die immer Energieverluste bedeuten, zu vermeiden.

Die Zeichnungen stellen in schematischer Darstellung einige beispielsweise gewählte Ausführungsformen der Erfindung dar. Fig. 1 zeigt einen schalenartigen Schirm an der Vorderseite eines Fahrzeuges, Fig. 2 einen mit einem konischen Schirm ausgerüsteten Vorderteil, die Fig. 3 und 4 zeigen in Seiten- und Vorderansicht parallel zueinander angeordnete Lamellen, wie sie zur Herstellung eines aus mehreren Blättern bestehenden Schirmes verwendet werden. Fig. 5 veranschaulicht in kleinerem Maßstabe den Vorderteil eines Fahrzeuges, der mit einem aus parallelen Lamellen gebildeten Schirm versehen ist, wobei diese Lamellen zu beiden Seiten einer Mittelrippe oder eines Grates angeordnet sind. Fig. 6 zeigt einen mehrteiligen konischen Bug in Vertikalschnitt.

Auf diesen Figuren stellen dar: *a* den Vorderteil eines beliebigen Fahrzeuges für die Fortbewegung zu Land, zu Wasser oder in der Luft, *b* den Schirm oder Bug und *c* einen Träger, der den Schirm mit dem Fahrzeug verbindet.

In den Fig. 3, 4, 5 und 6 sind die Lamellen, aus denen der Bug gebildet wird, mit b, b^1, b^2 bezeichnet. Die einzelnen Lamellen sind durch Zwischenstücke *d* (Fig. 5 und 6) miteinander verbunden.

Mit einem Schirm, der aus einer einzigen Serie von parallelen Lamellen besteht, wie sie in den Fig. 3 und 4 gezeigt sind, kann das Medium nur nach einer Richtung abgelenkt werden, die verändert werden kann, indem man die Stellung des Schirmes wechselt. Der Bug nach Fig. 5 ist zur Ablenkung des Mediums entweder nach den zwei Längsseiten des Fahrzeuges oder oberhalb und unterhalb desselben bestimmt, je nach der Lage, die man dem Schirm im Verhältnis zum Fahrzeuge gibt.

Ein konischer bzw. aus den Mantelflächen eines Kegelstutzes zusammengesetzter Schirm, wie in Fig. 6 veranschaulicht, bietet die Möglichkeit, das Medium um das ganze Fahrzeug herum abzulenken.

Die Form und die Anordnung der Platten kann in mannigfaltiger Weise abgeändert werden, ohne aus dem Rahmen der Erfindung herauszutreten.

PATENT-ANSPRÜCHE:

1. Einrichtung an Fahrzeugen zur Verminderung des Widerstandes des Mediums, dadurch gekennzeichnet, daß in einer entsprechenden Entfernung vor dem Fahrzeug ein Schirm von kleinerem Querschnitt als der des Fahrzeugvorderteiles mit geneigten, in einer Kante sich schneidenden oder den Mantel eines Kegels bildenden Flächen angebracht ist, derart, daß, wenn sich das Fahrzeug mit seiner normalen Geschwindigkeit fortbewegt, die Flächen des Bugs das begegnende Medium (Luft oder Wasser) so ablenken, daß dieses auf keinen Teil des Fahrzeugkörpers auftrifft.

2. Ausführungsform der Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die geneigten Flächen des Bugs durch eine Anzahl von Lamellen gebildet werden, zwischen welchen für das Medium Durchgänge oder Kanäle ausgespart sind.

3. Ausführungsform der Einrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Lamellen gekrümmt sind.

Zur Patentschrift
Nr 62320.

Fig.1.

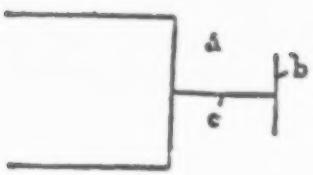


Fig.2.

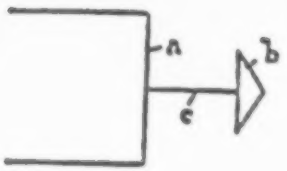
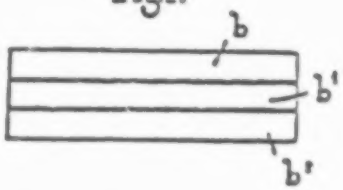


Fig.3



Fig.4.



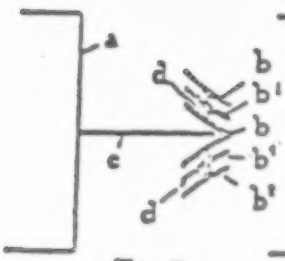


Fig.5.

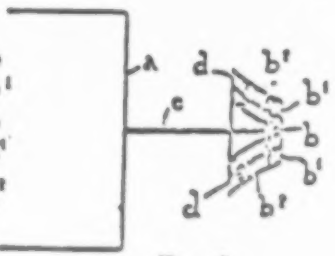


Fig.6.

A 108

Class 63c

Issued on November 25, 1913

IMPERIAL-ROYAL PATENT OFFICE

Austrian Patent 62,329

LOUIS CONSTANTIN of PARIS

DEVICE ON VEHICLES FOR REDUCING THE RESISTANCE TO MOTION

Filed on March 18, 1912; Priority of March 18, 1911
(Application in Spain)

Start of the Patent Life: July 1, 1913

CERTIFICATE OF ACCURACY

STATE OF NEW YORK)
COUNTY OF NEW YORK) ss:

This is to certify that on this day personally appeared before me, a Notary Public in and for the aforesaid State and County, Arthur Tannenbaum who, after being duly sworn, deposes and says:

"That he is a translator of the German and English languages;

That he is associated with TANNENBAUM TRANSLATION SERVICE;

That he is thoroughly conversant with these languages;

That he has carefully compared the attached English translation of the annexed document written in the German language;

That the said translation is a correct and true translation of such document and of the whole thereof"

/s/ ARTHUR TANNENBAUM
Translator

Sworn and subscribed to before me this 11th day of August 1982

/s/ NINA CHANEVICH
Notary Public

NINA CHANEVICH
NOTARY PUBLIC, State of New York
No. 41-4735528
Qualified in Queens County
Commission Expires March 30, 1983

[SEAL]

It is known to reduce the resistance of the medium during the movement of vehicles in water or in the air by endowing the front part of the vehicle with a tapered shape.

This arrangement, as it is used with ships, as well as with land vehicles and airships, provides between the front spine or the outermost part of the vehicle penetrating into the medium and the body of the vehicle a connection formed by sloped walls or inclined surfaces, which is integral with the body of the vehicle. The bow formed in this way is necessarily of little use or is poorly usable and burdens the vehicle with an increase in its deadweight that is in no way compensated for by an increase in its relative carrying capacity.

Furthermore, an improvement of an existing vehicle can, under these conditions, not be achieved otherwise than by the complete rebuilding of its front part, which is not always possible: as an example, we may cite an automobile with a closed body, such as a limousine, with regard to which one would not think of completely blocking the view by attaching to the body a tapered bow, forming with it an integral member.

The object of the present invention is, firstly, to make possible the building of vehicles that are very compact, that is, that have a large relative carrying carrying capacity and that, as a result of a specially shaped attachment of low weight and small volume, are at the same time characterized in that the resistance to motion of the medium in question becomes insignificant. Secondarily, the invention aims at the improving of existing vehicles in the same sense, i.e., without a significant increase in weight and without any major rebuilding of the vehicle.

The invention is based on the fact that the thin layers of the medium that are laterally displaced by a body in motion continue to remain deflected over a certain distance, even after they are no longer in contact with the said body, and that, in this deflection, they carry along the medium layers they encounter.

Therefore, if one attaches at a suitable distance ahead of the vehicle a shield of suitably shaped cross-section that is smaller than that of the front of the car, the layers of the medium that are reflected by this screen will remove out of the path of the car also other layers that, without the shield, would have struck the

vehicle and provided a resistance to the motion. It can thus be seen that the vehicle will in this case not have to overcome the resistance of a column of the medium that has the same diameter as its front part, but only that of a column of the diameter of the shield. Accordingly, there will occur a reduction of the resistance. It follows furthermore that this reduction will be that much more substantial the smaller the resistance upon the forward motion of the shield itself, of course, insofar as the capacity of lateral deflection of the latter does not appear to be reduced thereby.

This result is achieved, according to the invention, in that the walls of the shield are allowed to consist of surfaces intersecting at an angle, in which the plane of symmetry passing through the line of (the spine) can be horizontal or vertical, as required; the surfaces of the shield can also form the generated surface of a cone.

A very strong lateral deflecting force can be achieved in that the shield is designed not in the form of a single continuous surface but is made of a plurality of superposed sheets, with these sheets suitably having a curved cross-section, in order to prevent impacts and excessively abrupt deflections which always result in energy losses.

The drawings show schematically some embodiments of the invention, selected as examples.

Fig. 1 shows a disc-like shield on the front side of a vehicle;

Fig. 2 shows a front part outfitted with a conical shield;

Figs. 3 and 4 show as side and front view, sheets arranged parallel to one another, such as are used for the manufacture of a shield consisting of a plurality of sheets.

Fig. 5 illustrates, on a smaller scale, a vehicle front part equipped with a shield formed out of parallel sheets, with these sheets being arranged on both sides of a center rib or a spine.

Fig. 6 shows a multipart conical bow as a vertical section.

On these figures there represent: *a* the front part of any vehicle for the forward movement on land, water, or in the air; *b* the shield or bow, and *c* a support connecting the shield with the vehicle.

In Figs. 3, 4, 5, and 6, the sheets constituting the bow are designated by b, b^1, b^2. The various sheets are interconnected via spacers *d* (Figs. 5 and 6).

In a shield consisting of a single series of parallel sheets, as they are shown in Figs. 3 and 4, the medium can be deflected into one direction only, which can be modified by changing the position of the shield. The bow according to Fig. 5 is intended for the deflection of the medium either toward the two longitudinal sides of the vehicle or above and beneath same, depending on the position imparted to the shield with respect to the vehicle.

A conical shield or a shield assembled out of the generated surfaces of a truncated cone, as illustrated in Fig. 6, affords the possibility of deflecting the medium around the entire vehicle.

The shape and the arrangement of the plates can be modified in a variety of ways without departing from the scope of the invention.

CLAIMS

1. Device on vehicles for reducing the resistance of the medium, characterized in that at a coresponding distance ahead of the vehicle there is mounted a screen of a smaller cross-section than that of the front part of the vehicle, with sloped surfaces intersecting in an edge of forming the generated surface of a cone so that, when the vehicle moves forward at its normal speed, the surfaces of the bow deflect the medium (air or water) being encountered in such a way that same does not strike any part of the vehicle body.

2. Mode of realization of the device according to Claim 1, characterized in that the sloped surfaces of the bow are constituted by a plurality of sheets between which there have been recessed passages or ducts for the medium.

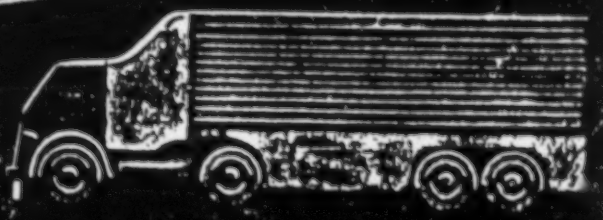
3. Mode of realization of the device according to Claim 2, characterized in that the sheets are curved.

APPENDIX M

PAGE

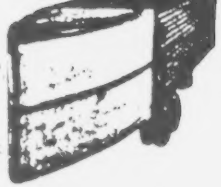
Booklet Published by Trailmobile Inc. A113-A128

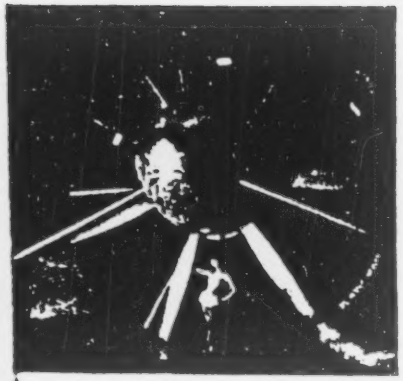
wind resistance

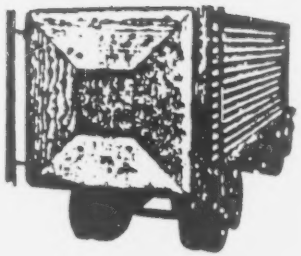


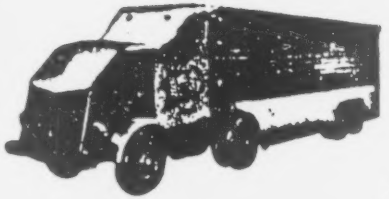
A research-study from the subsonic wind tunnel at the University of Maryland — showing data on the cause and effect of aerodynamic design on commercial trailers

A 113











In this booklet...

Page 3... *The Point of Diminishing Return* by Professor A. Wiley Sherwood.

Pages 4 and 5.... What is a Wind Tunnel and how does it work?

Page 6... Preparations for Wind Tunnel tests to show effect of wind resistance on truck-trailers.

Page 7... What is Wind? How does it affect trucking operations?

Pages 8 and 9.... Various combinations of truck-trailer designs and their effect on wind resistance.

Page 10.. How trailer front corner radius designs effect changes in wind resistance and horsepower requirements.

Page 11.. How wind resistance varies when both the trailer's front *roof and corner* radius is changed.

Page 12.. What part do the sides of trailers play in decreasing or increasing wind resistance?

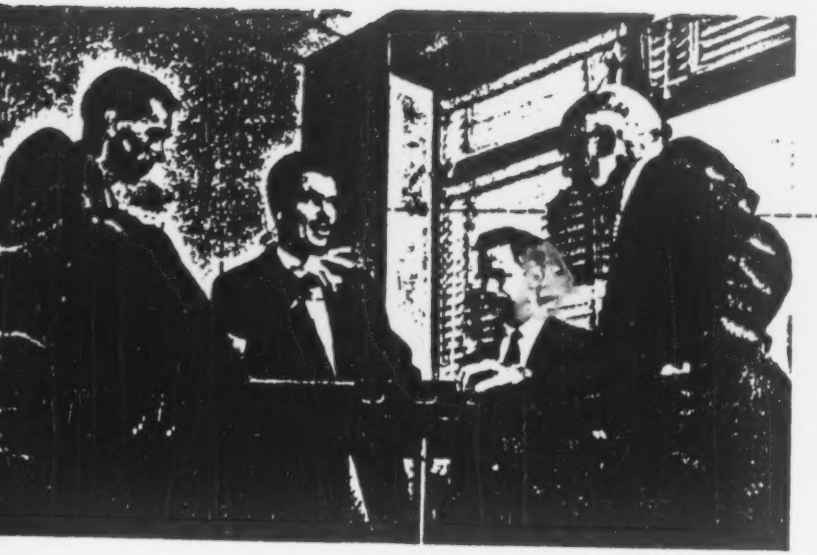
Page 13.. Average fuel savings when the trailer front and side are tested in various combinations.

Pages 14 and 15... Aerodynamic tests to discover how design changes effect wind resistance.

Page 16.. An important conclusion; the future outlook for equipment streamlining in relation to cubic capacity.

A 114

"The point of diminishing return . . ."



A. Wiley Sherwood,
Professor of Aerodynamics,
Manager of Wind Tunnel Research
University of Maryland
College Park, Maryland

"**There is a point of diminishing return** in the design of aircraft and in truck-trailers. In aircraft, the point is reached when streamlining sharpens to the degree where there is no longer sufficient room for pilots and fighting gear.

"*In truck-trailers, the point of diminishing returns takes place when exterior streamlining eats into interior cargo space.*

"*Where is that point?*"

"The following pages define this elusive point, and for the first time show the results of Wind Tunnel tests on various areas of truck-trailers."

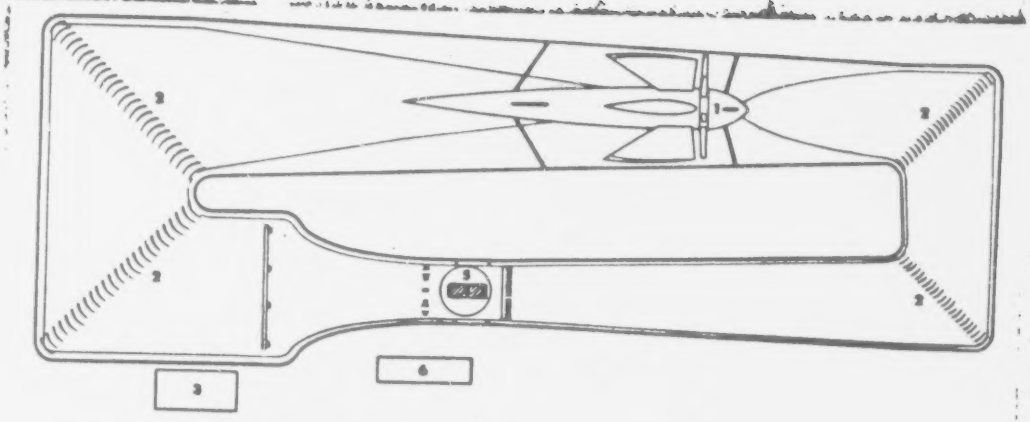
A 115

What is a *WIND TUNNEL* and how does it work?

Up to this time, wind tunnels have been used almost exclusively to test advanced aeronautical designs. The wind tunnel can simulate actual flight conditions which affect airplanes, and air flow over various surfaces. Likewise, the wind tunnel can tell trailer manufacturers how their products react to wind drag. Engineers and designers must know how their finished product will perform—how much drag, lift and yaw will result from a design change in a wing, nose, front, tail or side assembly, or in the case of trailers, the fronts, roofs, sides, rear end assemblies and undercarriages of trailers.

Important parts of the University of Maryland Wind Tunnel, numbered below, correspond with those in the scale drawing at right:

1. 2250 horsepower fan creates winds up to 150 miles per hour.
2. Giant water-cooled deflecting vanes guide wind around corners of tunnel and reduce turbulence so that wind flow over trailer is smooth.
3. Power supply station for operation of 2250 H.P. electric motor to generate 150 m.p.h. air current.
4. Working section of wind tunnel. Note that this area is compressed into a "bottle neck." Here is where the wind reaches its highest velocity and where the model truck-trailers to be tested are placed.
5. Turntable operates in a complete 360° circle so that the wind can strike the trailer model being tested from every possible angle. Wind drag readings are taken by electronic computing devices at every angle—full front, three-quarter front, full side, three-quarter rear, full rear to check variation in drag.
6. Wind tunnel control room where operator-engineers control speed of wind and the angle of the trailer model being tested.

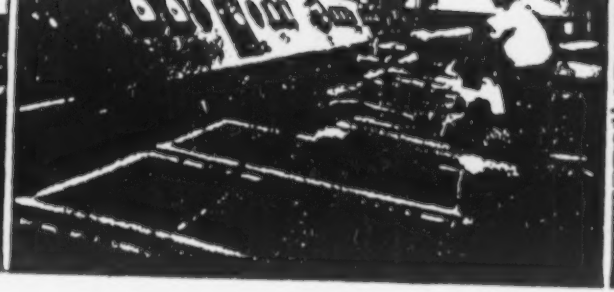


The University of Maryland Wind Tunnel is 166 feet in length and 60 feet in width.

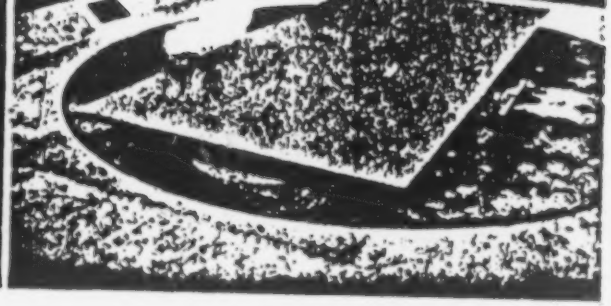
A 116



Wind Tunnel Control Room as viewed from the wind tunnel. Note exact scale model wood parts on table awaiting assembly.



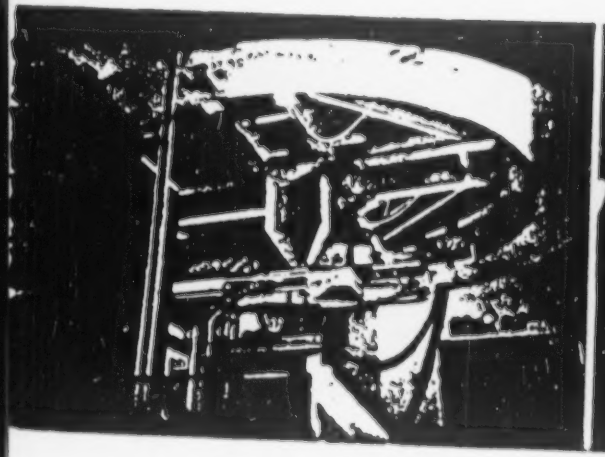
Console Board in control room. From here the engineer can control the wind speed and the angle of the model into the wind.



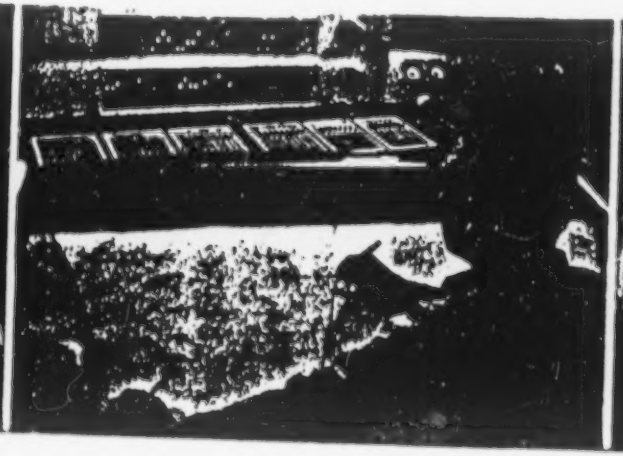
Ground Board and Balance Turntable in working section of wind tunnel. As wind strikes model the "drag" is transmitted through steel pins to electronic IBM equipment. Turntable directs test model into wind at any angle.

5

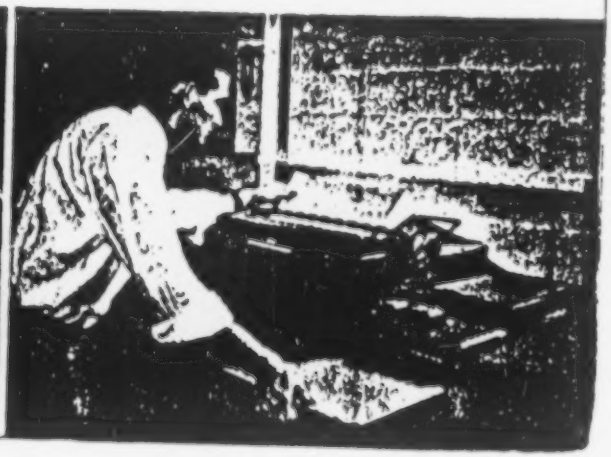
Underside of Balance Turntable shows complex equipment and delicate balance required to give engineers exact readings taken from model being tested on turntable.



Take-off Board shows information being gathered during wind tunnel test run. When model under test is set at correct angle, operator takes a test reading seen on this IBM Data Board.



IBM Data Recorder prints test result information automatically for further calculation and study by engineers.



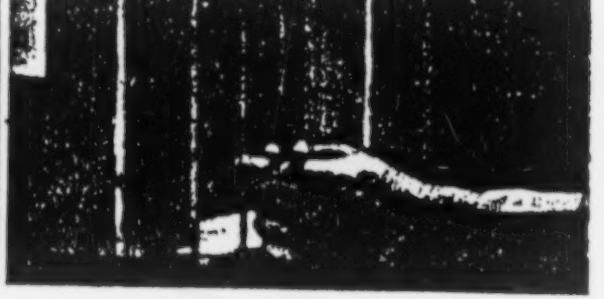
A 117

Preparing for the first test-research study

...to show the effect of wind resistance on truck-trailers. Tests conducted at the University of Maryland Wind Tunnel

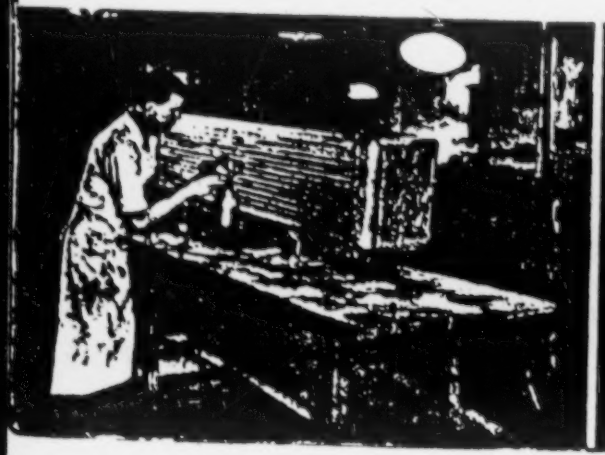


Mapping out aerodynamic test-research projects to find the effect of air drag on truck-trailer designs are (left to right): J. J. Black, Vice President in charge of Engineering, Trailmobile; W. R. Hummel, Chief Engineer, Trailmobile; A. Wiley Sherwood, Professor of Aerodynamics and Manager of Wind Tunnel, University of Maryland; Paul Jung, Test Engineer, Trailmobile.



Two test side panels are carefully calibrated to meet exacting wind tunnel requirements. Wood used for top, fronts, sides and most rear end testing is imported mahogany.

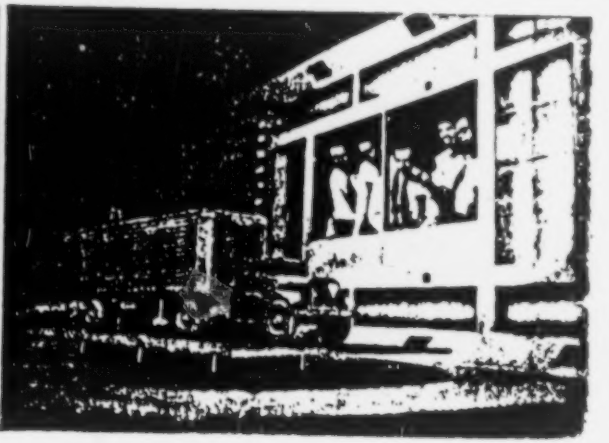
Wind tunnel worker adds finishing touches to exact ¼ scale model Trailers in preparation for aerodynamic test-research. Models are made from full scale blue prints to assure accurate test readings.



Multi-tube Manometer Board gives test engineers pressure readings from as many as 100 points on the trailer model being wind-tunnel tested.



"Operation Wind Tunnel" Test Phase I, ready to begin, receives final approval from wind tunnel and Trailmobile engineers. Tractor-trailer is facing directly into wind stream at this point. Soundproof window separates wind tunnel from control room.



What is WIND?

There are two kinds of wind which affect trucking operations

The first kind of wind with which we are familiar is the kind created by nature—air moving from high pressure areas to low pressure areas. This is the wind that keeps kites in the air and turns umbrellas inside out. Believe it or not, this kind of wind has an average speed in the United States of only ten miles an hour which barely amounts to a noticeable breeze.

This kind of natural wind does not appreciably affect the air drag on your trucks or trailers since it might be blowing from any direction and will average out as coming from all sides over a period of time.

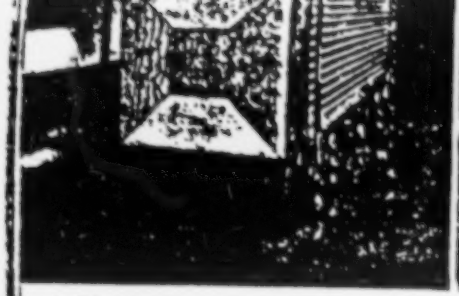
The second kind of wind does affect your trucks and trailers—to a very marked degree. *This is the "wind" that pushes against, or causes resistance to your vehicles as they pass through the air. At 50 mph your truck or trailer "creates its own wind," a 50-mile-an-hour wind.* This is the wind you feel when you ride in a convertible automobile.

The more streamlined the vehicle, the more easily it will pass through the air. And it will require far less power to pass it through the air which means a definite savings in horsepower, gasoline, oil and friction.

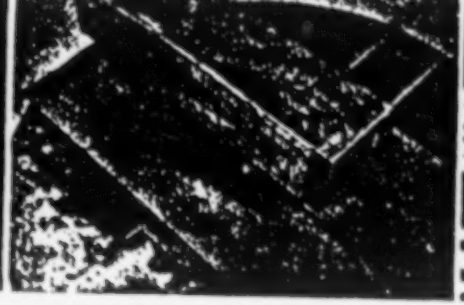
The Wind Tunnel tests on the following pages prove that correct design and streamlining increases usable horsepower, decreases air drag and contributes materially to the economy of operation and the ease of handling of truck-trailers.

In order to make this report brief and in a form that is easy to understand we have not shown the effects of natural winds. However, these tests were made and figures are available.

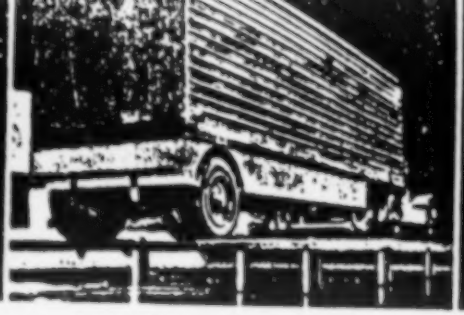




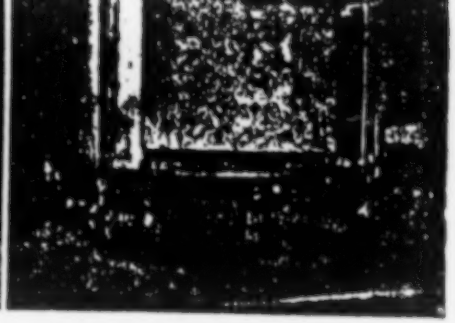
1. Rounded rear-ends, air deflecting vanes, corrugated sides.



2. Square front, vertical post (bird's eye view).



3. Drop frame with corrugated sides.



4. Square rear-end with guide vanes top and sides.

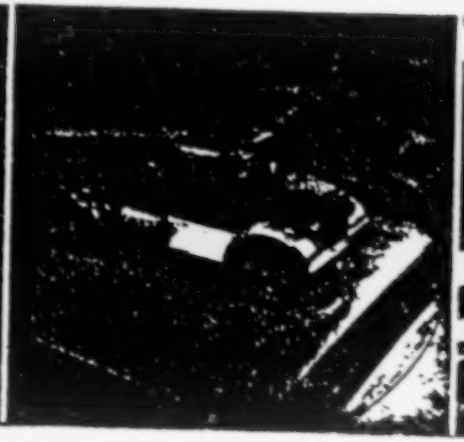
Over 7000 combinations

of design were tested in the Wind Tunnel—shown here are but a few of those test designs. No possibility was overlooked in an effort to find ways and means to reduce wind resistance of the truck-trailer unit.

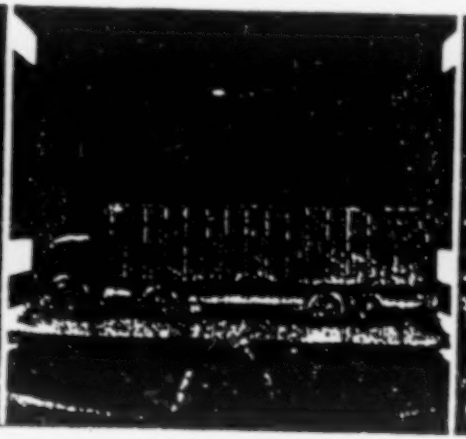
A 120



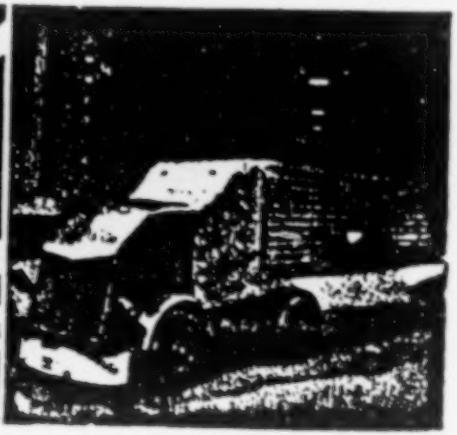
Horizontal corrugated sides with square front and COE west coast tractor.



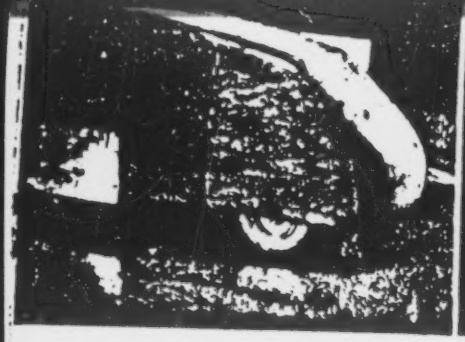
10. Conventional single axle tractor.



11. Vertical post sides with 6° Radius nose cap and COE tractor.



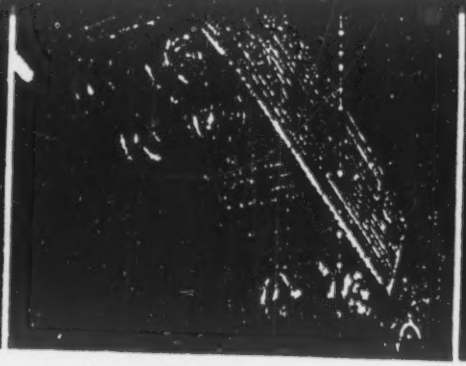
12. COE tractor with deflector under bumper, corrugated sides, skirting, and enclosed space between trailer and cab.



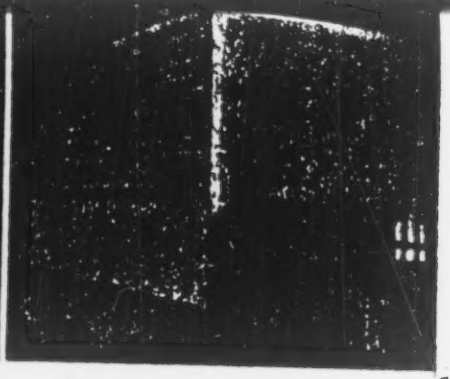
5. Tractor with rounded nose flared into trailer body.



6. Horizontal corrugated model with rounded front corners.

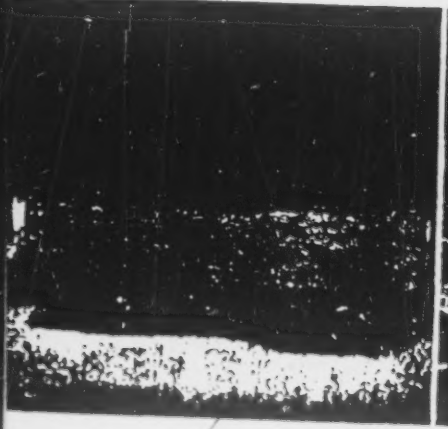


7. Horizontal corrugated sides, bolsters removed from undercarriage.

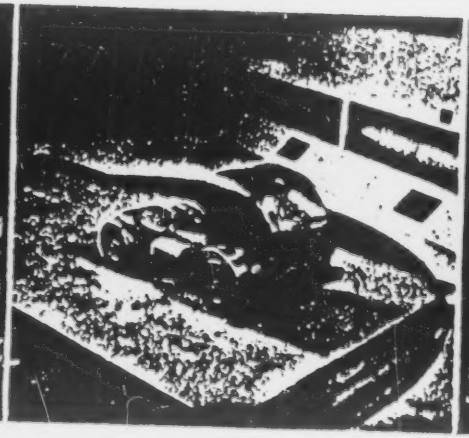


8. Horizontal corrugated sides with skirts and rounded rear-end.

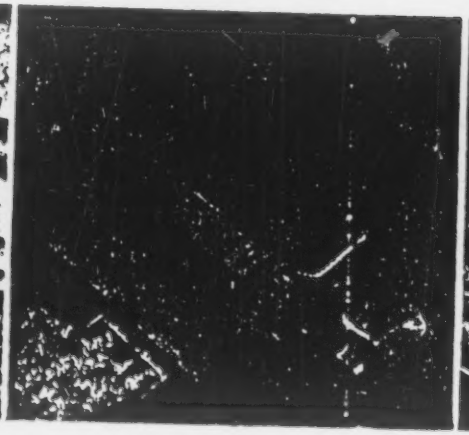
9



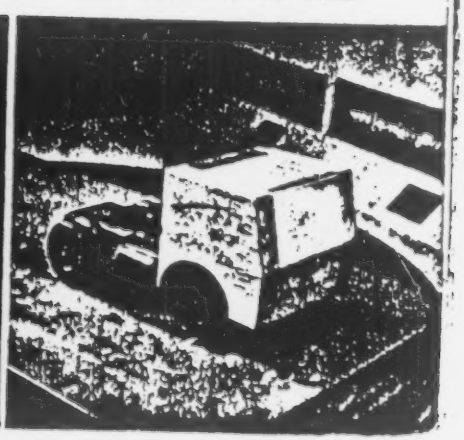
13. Smooth panel sides with rounded front end.



14. COE tractor.



15. Horizontal corrugated sides with rounded front and COE tractor.



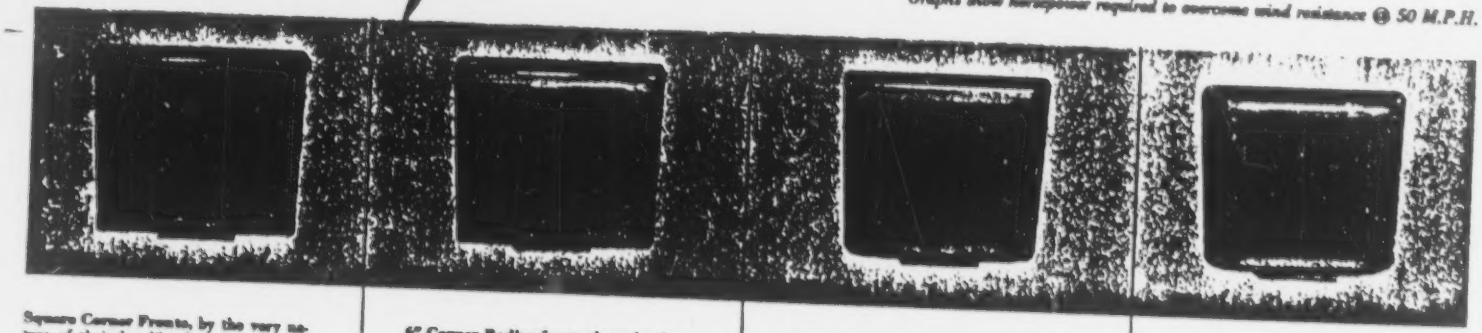
16. COE west coast tractor.

A 121

TEST PHASE NO. 85

Changing only the front corner radius of the trailer directly affects its wind resistance

Graphs show horsepower required to overcome wind resistance @ 50 M.P.H.



Square Corner Fronts, by the very nature of their box-like design, have high air drag characteristics. Aerodynamically, this front showed the most wind resistance.

54 H.P.

6" Corner Radius fronts showed a sharp reduction of 11.8% when compared to the square corner fronts.

47.6 H.P.

12" Corner Radius fronts did not show any appreciable decline in wind resistance (13.9%) over the 6" corner radius front. The 12" radius also creates certain tractor-trailer clearance problems.

46.5 H.P.

18" Corner Radius fronts showed a 14.8% reduction in wind resistance over the square front and an improvement over the 12" corner radius. The 18" corner radius also provides ample tractor-trailer clearance.

46.0 H.P.

The Wind Tunnel tests on this page show how wind resistance varies as the front corner radius is changed.

Fig. 1. The front design that shows the most wind resistance is, quite naturally, the square front as seen in Fig. 1. The square front requires 54 H.P. just to overcome wind resistance at 50 miles-per-hour.

In Fig. 2, it is evident that simply by rounding the two front corners with a 6" radius, only 47.6 H.P. is required to overcome wind resistance at 50 miles-per-hour. This is a reduction of 11.8% in horsepower requirements.

Fig. 3 proves that there is little to be gained in a 12" corner radius front over the 6" corner radius front. However when compared to a square front the difference amounts to a reduction of 13.9% in horsepower requirements to overcome wind resistance. But the 12" corner radius trailer creates certain tractor clearance problems.

Fig. 4, using an 18" front corner radius, shows the greatest reduction in wind resistance of the four front corner radius tested. The 18" corner radius front required only 46 H.P. to overcome wind resistance at 50 miles-per-hour. This is a reduction in horsepower requirements of 14.8% over the completely square front trailer. The 18" corner radius front also eliminates tractor clearance problems.

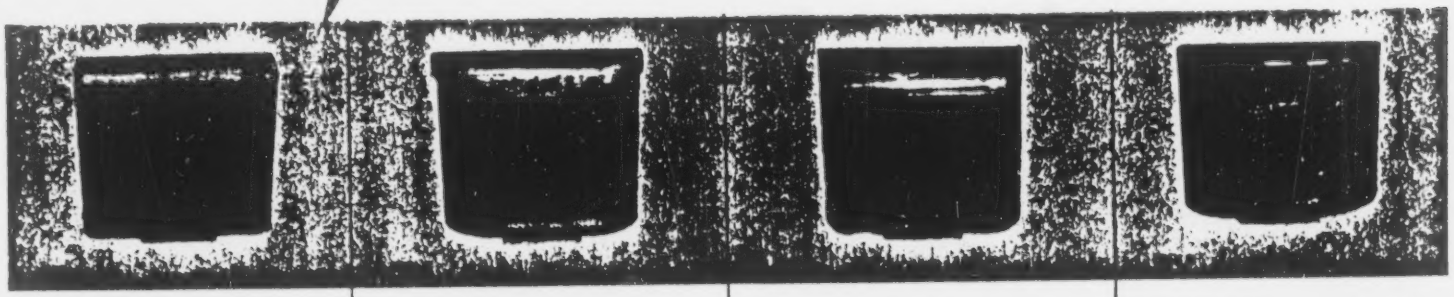
A. 122

Operation Wind Tunnel

TEST PHASE 85-A

Varying both the front corner radius and the roof radius of the trailer results in even greater differences in wind resistance

Graphs show horsepower required to overcome wind resistance @ 50 M.P.H.



6" Corner Radius front and 6" Roof Radius proved to be good since it reduced wind resistance 21.1% over the square front yet maintained full inside front loading advantages.

42.6 H.P.

18" Corner Radius fronts with 6" Roof Radius was one of best fronts tested. This front showed a remarkable 23.5% drop in wind resistance.

41.3 H.P.

18" Corner Radius fronts with 18" Roof Radius showed no reduction in wind resistance over the 18" corner radius front with 6" roof radius.

41.3 H.P.

The Oval Front proved to have the least wind resistance of all front designs tested—28.5%. However the oval front reduces the inside cubic capacity of the trailer and tends to offset the savings from streamlining.

38.6 H.P.

The Wind Tunnel tests on this page show to what degree wind resistance changes as both corner and roof radius are varied.

Fig. 5, with a 6" corner radius front and a 6" roof radius results in a 21.1% reduction in wind resistance when compared to the square front end trailer. Only 42.6 H.P. are required to overcome wind resistance with the 6" corner and 6" roof radius combination, as against 54 H.P. for a square front trailer.

Fig. 6 shows what happens when an 18" front corner radius trailer is used in combination with a 6" roof radius. Here, only 41.3 H.P. is required to overcome wind resistance as against 54 H.P. for a square front trailer. This amounts to a 23.5% reduction in wind resistance.

Fig. 7 is the same as Fig. 6 except the roof radius was increased from 6" to 18". This did not result in a reduction in wind resistance or a decrease in horsepower requirements over the 18" front corner radius and 6" roof radius as shown in Fig. 6.

The oval front, **Fig. 8**, proved to have the least wind resistance of all fronts tested in the Wind Tunnel. It showed that only 38.6 H.P. was required to overcome wind resistance—a reduction of 28.5% in horsepower requirements over the square corner front. However the oval front sacrifices an excessive amount of inside cubic capacity, which in the long run could result in losses of revenue which would far outweigh its benefits in decreased wind resistance. This is a prime example of how the point of diminishing return operates.

What this means to you as an operator . . . Using a regular square-front trailer as the basis for comparison it requires 54.0 horsepower at 50 mph to overcome "air drag" or wind resistance.

Using the 18" radius corner

@ 40 mph air drag reduction saves 5.12 h.p.
@ 50 mph air drag reduction saves 8.0 h.p. } or 14.8%
@ 60 mph air drag reduction saves 11.5 h.p.

Using the 6" radius —corner and roof

@ 40 mph air drag reduction saves 7.3 h.p.
@ 50 mph air drag reduction saves 11.4 h.p. } or 21.1%
@ 60 mph air drag reduction saves 16.4 h.p.

Using the 18" radius corner with 6" roof radius

@ 40 mph air drag reduction saves 8.1 h.p.
@ 50 mph air drag reduction saves 12.7 h.p. } or 23.5%
@ 60 mph air drag reduction saves 18.3 h.p.

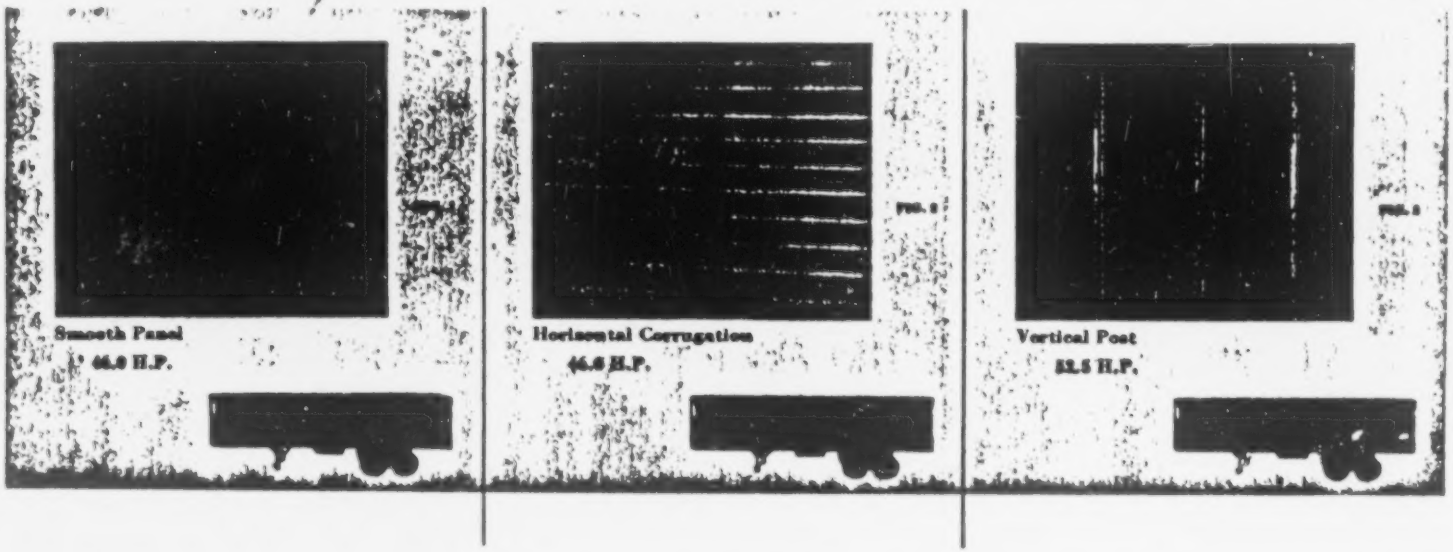
A 123

Operation Wind Tunnel

TEST PHASE 98

Wind resistance is increased or decreased, depending on the design of the trailer side

Figures show horsepower required to overcome wind resistance @ 50 M.P.H.



As many truck operators have long contended, the type of trailer side plays a large part in decreasing or increasing wind resistance. On certain hauls this can affect gasoline and oil consumption, engine wear and horsepower requirements and ease of handling of the tractor-trailer unit.

Fig. 1 & 2: The smooth panel trailer side (Fig. 1), and the horisontal panel side (Fig. 2), when tested in the Wind Tunnel show that only 46 H.P. are required to overcome wind resistance at 50 miles-per-hour.

Fig. 3: The vertical post design trailer (Fig. 3), results in a higher degree of wind resistance, according to Wind Tunnel tests. This type of side requires 52.5 H.P. to overcome wind resistance at 50 miles-per-hour. This is an increase of 14.1% over the smooth side design trailer.

A 124

Operation Wind Tunnel

TEST PHASE 98-A

Average fuel savings for various trailer front and side combinations.

(Cross-reference of side and front design and their effect on horsepower requirements are based on 50 m.p.h. truck speeds)

Listed on the chart at right are various combinations of side designs as related to front designs. In each case the H.P. figure represents the horsepower drag of wind resistance at 50 mph. The dollar figures shown represent the estimated annual savings in fuel costs of these combinations as compared to a vertical post trailer with a square front (as indicated by "Base").*

These figures may also be used to estimate annual savings of other combinations. For example, to compare a trailer with a square front smooth panel side versus a trailer with 18" corner radius front and smooth panel side:

$270.00 (18" radius front, smooth side panel)

—95.00 (square front, smooth panel side)

$175.00 approximate annual savings

*These figures are based on the following:

Annual mileage 60,000 miles
fuel consumption 4 miles per gallon
fuel cost $0.24 per gallon
54,000# gross vehicle weight
average speed 50 mph

Special Note: The above figures are based on averages. The conclusions are one way of several, to evaluate horsepower savings. Computations were derived from figures obtained in the 1954 S.A.E. Handbook "Truck Ability Prediction Procedure" and Wind Tunnel Test data.

For specific savings that you can expect in your operation, fill in all details on the attached reply card.

	Vertical Post	Smooth Panel	Horizontal Corrugated
Square Front	53.3 H.P. Estimated Annual Fuel Savings BASE	54.0 H.P. Estimated Annual Fuel Savings $95.00	54.0 H.P. Estimated Annual Fuel Savings $95.00
6" Radius Corners 6" Radius Roof	49.8 H.P. Estimated Annual Fuel Savings $190.00	42.6 H.P. Estimated Annual Fuel Savings $345.00	42.6 H.P. Estimated Annual Fuel Savings $345.00
18" Radius Corners	53.5 H.P. Estimated Annual Fuel Savings $130.00	46.0 H.P. Estimated Annual Fuel Savings $270.00	46.0 H.P. Estimated Annual Fuel Savings $270.00
18" Radius Corners 6" Radius Roof	49.2 H.P. Estimated Annual Fuel Savings $200.00	41.3 H.P. Estimated Annual Fuel Savings $375.00	41.3 H.P. Estimated Annual Fuel Savings $375.00

A 125



Ideas and design changes show attempts to decrease trailer wind resistance

On these pages are design attempts to find new ways to reduce wind resistance. The color bar and the part of each trailer model shown in green is that part where design changes have been made.

In each case, design changes were measured and compared to a trailer with smooth sides, an 18" corner radius front and 6" radius roof, connected to a tractor of conventional design moving at a speed comparable to 50 miles-per-hour.

With Cab To Body Space Filled was found the largest single contribution to drag reduction. Although impractical at this time, serious study is being given this important area for future development.

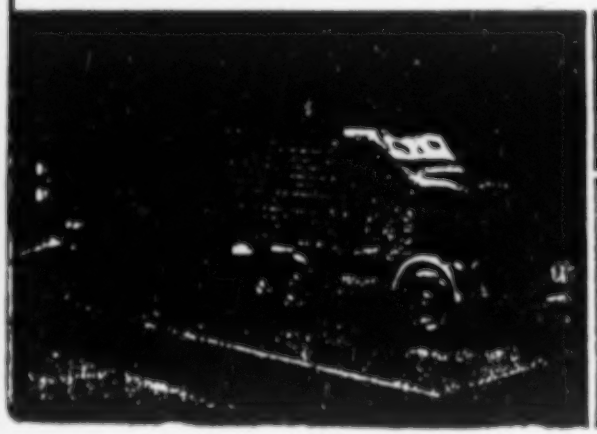
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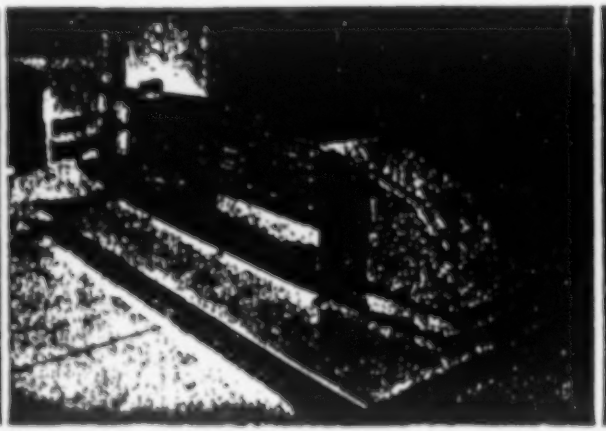
Fully Streamlined Tractor-Trailer—this combination approaches the ideal aerodynamic tractor-trailer design. Drag of this unit is only about 1/5 of that obtained with conventional tractor-trailer combinations, but existing state laws make this near-ideal combination impractical for now.

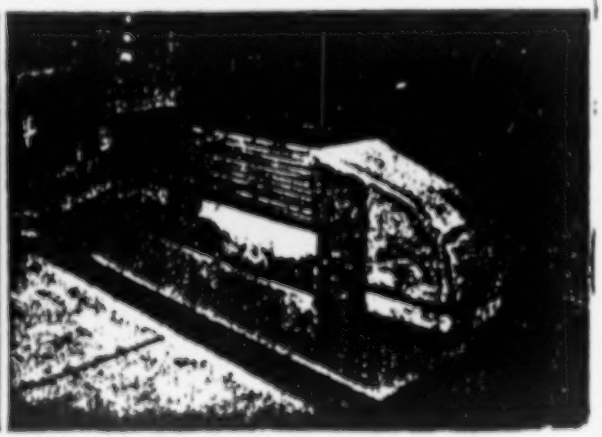
[redacted] Combination 8.1 H.P.

Streamlined Combination Without Boattail—this streamlined combination allowed a smooth flow of air along the tractor and trailer side and top surfaces and resulted in a drag reduction of 63%. This combination may prove practical in modified form in the near future.

Conventional Combination [redacted] tion 15.2 H.P.

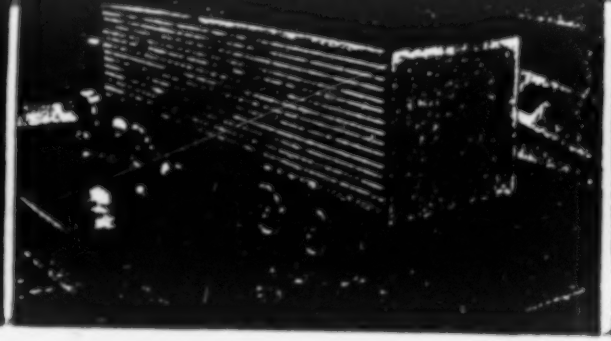


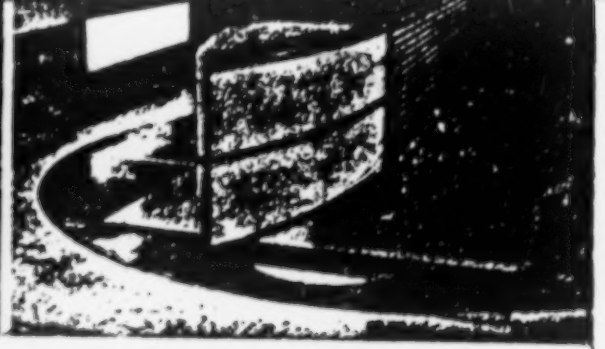




A 126







Cobble Vanes—the test use of guide vanes was an unsuccessful effort to obtain a drastic reduction in air drag. Based on previous European tests these were expected to deflect the air in such a manner as to cause a reduction in air drag on the trailer. However, tests proved negative.

[redacted]

Rounded Rear Corners—are not effective in reducing drag since the so-called "vacuum" at the rear of the trailer was insignificant.

[redacted]

"Beaver Tail"—the application of a "Beaver Tail" to a trailer reduces the drag by 12%, but the extra length of this combination cargo space makes it impractical for present day use.

[redacted]

This Semi-Streamlined combination provided a 37% drag reduction. At this time it is impractical to enclose the spacing between tractor cab and trailer, but it may open possibilities for future design improvements.

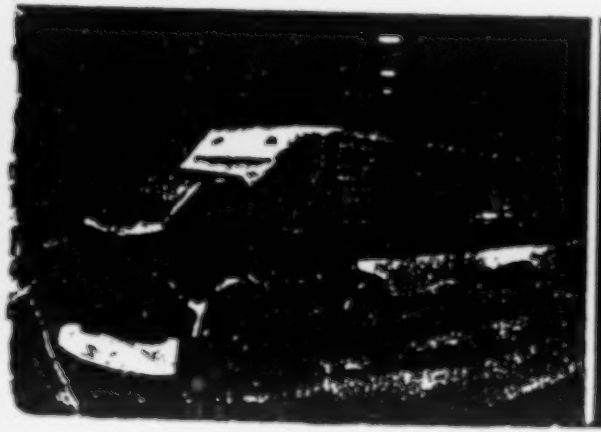
[redacted] H.P.

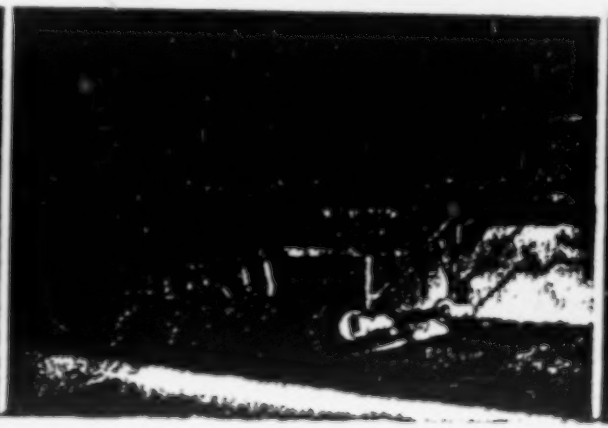
The Flap mounted at the rear of the tractor frame blanked the flow of air beneath the trailer and created an additional 2.3% drag instead of an anticipated air drag reduction.

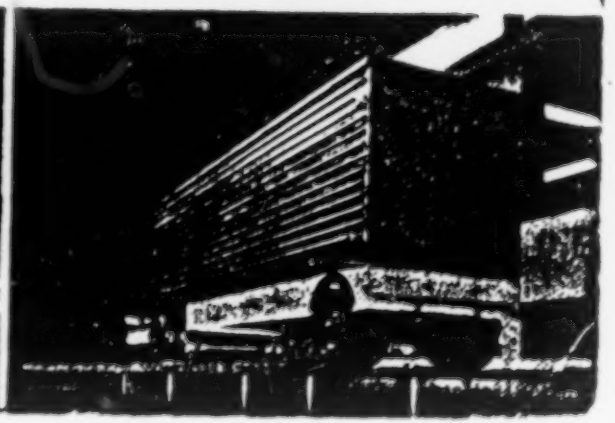
[redacted]

Adding A Drop To The Trailer created a 2.9% increase in the drag. This indicates that wind resistance problems of the drop frame trailer are basically the same as the straight frame.

[redacted]









An important conclusion . . . .

of interest to all members of the trucking industry

For several decades the question of wind resistance and air drag versus the streamlining of truck-trailers has been the subject of wide discussion in the trucking industry. Trailmobile, in cooperation with the American Trucking Associations Foundation, Inc., decided to find out once and for all just what the facts were. "Operation Wind Tunnel" is the result.

Some of the most important findings are published in this booklet. They are offered to the trucking industry as a service to further understanding and to result in a more economical trucking operation.

Wind Tunnel data indicate the drastic streamlining of front-ends to be highly desirable, but impractical under today's legal length restrictions. It was found that the correct front-end design on a trailer can save users as much as 23.5% in horsepower requirements to pull through the air, as against a trailer with a square front-end.

These savings when added together over the months and years are too important to be overlooked. They can materially reduce current high operating costs. New design advances resulting from these tests mean even easier handling and smoother pulling of the trailer unit on the highway.

Certain trailer side designs when used in conjunction with rounded front ends also result in easier handling and economy of operation.

The continuing trend toward demand for increased cubic capacity means that trailer manufacturers must provide both—outside streamlining and more usable inside freight space. Neither factor by itself is a satisfactory answer. The trailer of the future, the near future, must have maximum cubic capacity and maximum practical streamlining in design to give the trucking industry the economy of operation it requires to go forward.

This booklet is published by Trailmobile Inc., in conjunction with the American Trucking Associations Foundation, Inc., as a joint test-research project on behalf of the Trucking Industry. Address all inquiries to Trailmobile Inc., Cincinnati 9, Ohio. Attention: Wind Tunnel Data Department.

A 128

APPENDIX N

PAGE

District Court Trial Exhibits

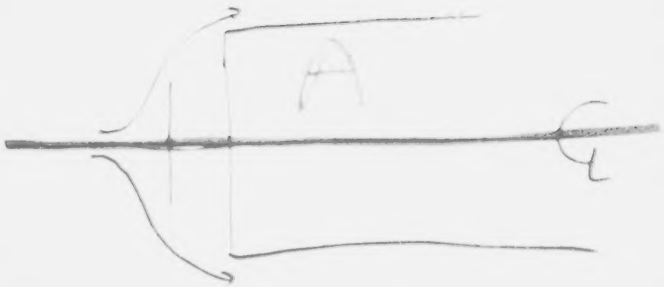
Plaintiff Exh. 419 ..... A129

Defendant Exh. KO..... A130

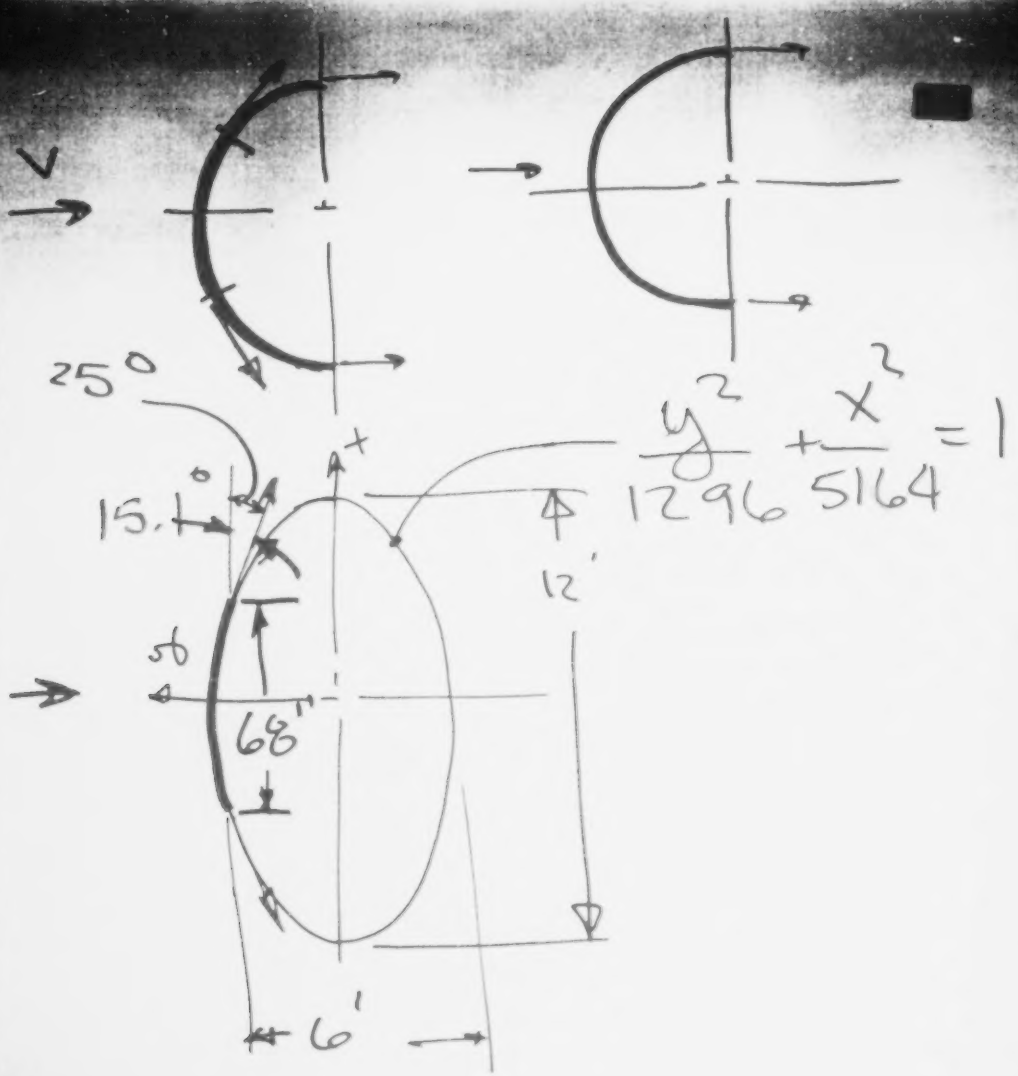








Plaintiff's Exhibit No. 419
Case No. N75-51
Date 11-26-82



Defendant's Exhibit No. 50
File No. N75-51
Date 11-15-82